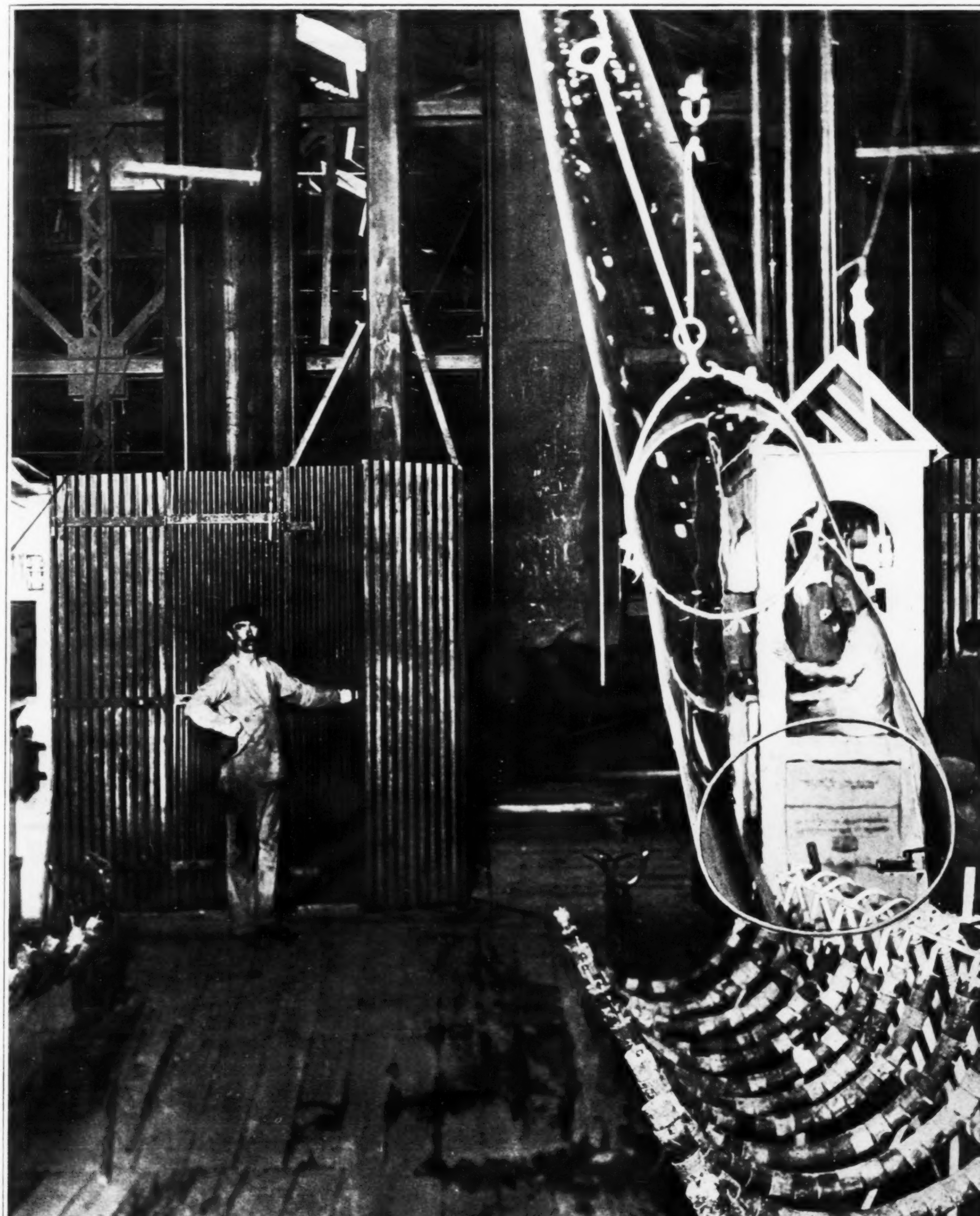
SCIENTIFIC AMERICAN SUPPLEMENT

VOLUME LXXXVIII
NUMBER 2275

NEW YORK, AUGUST 9, 1919

Published weekly. Entered as second class matter December 15, 1887, at the Post Office at New York, N. Y., under Act of March 3, 1879

10 CENTS A COPY
$5.00 A YEAR



Copyrighted by National Geographic Society.

A machine-blown cylinder of window-glass being lowered from the drawing machine into its cradle

(Courtesy of American Window Glass Co.

WINDOW GLASS (See page 88)

Chemistry of Rubber*

Development in Our Knowledge of Caoutchouc from Columbus to Our Own Times

By S. C. Bradford, B.Sc.

INDIARUBBER, or caoutchouc, is essentially a hydrocarbon, produced from a watery emulsion, or latex, obtained by tapping many tropical and sub-tropical trees, notably *Hevea braziliensis*. The first rumors of the existence of rubber are said to have reached Europe after the second voyage of Columbus to the New World in 1493-4, during which the natives were found to be in the habit of making playing-balls, bottles, waterproof boots and various other articles of a curious elastic gum. The earliest known reference to the substance occurs in a description by P. Martyr d'Anghiera in 1525, of some playing-balls seen by him in Mexico. Father Xavier de Charlevoix describes the ball as of a solid matter, but "extremely porous and light. It soars higher than our balls, falls on the ground, and rebounds much higher than the level of the hand which it quitted; it falls back again, and rebounds once more, although not to such a height this time, and the height of the bounce gradually diminishes." The Indians in Ecuador and Peru called the material "cahuchu" or "caucho," from which names the term "caoutchouc" was derived. Occasional samples were brought to Europe by travellers to adorn the curiosity cabinets of collectors. It was worth a guinea an ounce.

In 1731 two expeditions were organized by the Académie des Sciences to determine the figure of the earth. One of these, under the naturalist La Condamine, and Bouguer, an astronomer and mathematician, sailed to the tropical regions of South America. La Condamine occupied his leisure in studying the flora and fauna of Peru and Brazil. And in 1736 he sent a small piece of rubber to the French Academy with a covering note in which he said: "There grows, in the forests of the province of Esmeraldas, a tree called by the natives of the country 'Hévé;' there flows from it, by simple incision, a liquor, white as milk, which gradually hardens and blackens in the air. The inhabitants make flambeaux of it . . . and boots which do not draw water, which, after having been blackened by holding them in the smoke, have all the appearance of real leather. They coat earthen molds in the shape of a bottle with it, and, when the resin is hardened, they break the mold and force out the pieces through the neck and mouth; they thus get a non-fragile bottle, capable of containing all kinds of liquid." La Condamine was unable further to pursue his investigations, but, at his suggestion, Fresneau, an engineer, stationed at Cayenne, made an exhaustive inquiry into the source and preparation of rubber, the account of which was communicated by La Condamine to the Académie des Sciences in 1751.

The first chemical study of caoutchouc was published by Hérissart and Macquer in 1763, who examined the behavior of the material towards various solvents. But the substance appears to have remained a mere curiosity in Europe, until in 1770 Priestley, the discoverer of oxygen, suggested its use, under the name of India rubber, for erasing lead pencil marks. And this was, for many years, the main purpose to which it was devoted, although Grossart showed how to make small tubes by cutting the bottles into strips, which were softened in ether, or essential oil, rolled on a mandrel and allowed to dry, when the surfaces amalgamated. In 1785 M. Charles, who made the first ascent in a balloon filled with hydrogen, coated his aerostat with rubber dissolved in turpentine. Suggestions for making clothing waterproof were made by Peal and Besson in 1791, Johnson in 1797, Champion in 1811, and Clark in 1815. None of these met with much success. In 1820 Nadier discovered a method of cutting indiarubber into thread for making elastic fabrics. And in the same year Hancock founded in England the first rubber factory. But it was not until about 1825 that Mackintosh discovered the solubility of rubber in naphtha and successfully applied the solution to the fabrication of waterproof garments, from which time the modern rubber industry may be said to commence. In 1836, in consequence of the researches of Hancock, it was found that rubber could be welded into masses by energetic kneading under the action of moderate heat. The process was termed mastication and solved the problem of the manufacture of articles of daily use.

The material was quickly applied to the preparation of goloshes, bottles and many other objects. And, in the United States particularly, vast sums of money were invested in mills and plant for the manufacture of rubber goods. The discovery that these articles were subject to the influences of the seasons caused widespread consternation, so many had an interest in the success of the gigantic speculation. Experience showed that in hot weather the substance melted and became adhesive, while in the cold it became obstinately brittle. A panic ensued, thousands of tons of rubber were thrown upon the market, and the immense capital became literally valueless.

It was now that Goodyear of New Haven, Conn., determined, at all hazards, to save something from the wreck. Inspired with the belief that Nature would scarcely have disclosed so many of the merits of indiarubber unless it possessed additional qualities of value to mankind, and oblivious of opposition and scorn, he devoted himself to the prosecution of the research. After suffering much hardship and even imprisonment for debt, he was rewarded in 1839 by the discovery of the process of vulcanization, which overcame the influence of seasonal changes and adapted the material to countless purposes of mankind. The result was attained by heating the gum with an admixture of sulphur to a temperature of 270° F. In 1844 Hancock observed that the same result was obtained by dipping crude rubber into melted sulphur. Two years later he patented a method for molding objects in caoutchouc, which was the starting-point of molds for solid and hollow articles. The greatest impetus it ever received was undoubtedly given to the industry by the reinvention, in 1888, of the pneumatic tire. An air-filled tire for use with carriages had been patented by Thomson in 1845, but, partly owing to faulty construction and partly because its advantages at low speeds were not sufficient to counter-balance the high cost of the large tires employed, the invention had been allowed to drop. The advent of the safety bicycle, with small wheels to which springs could not easily be attached, led Dunlop independently to discover and patent the idea.

Previous to the utilization of rubber in the chemical laboratory, apparatus was connected, if possible, by means of glass tubes bent twice at suitable angles. Occasionally one piece of apparatus was ground to fit another. Otherwise, for such purposes as connecting retorts with receivers, lutes were used. Thomson says, in his *System of Chemistry*, sixth edition, 1820: "The lute most commonly used by chemists, when vessels are exposed to heat, is fat lute, made by beating together in a mortar fine clay and boiled linseed oil. . . . The accuracy of chemical experiments depends almost entirely, in many cases, upon securing the joinings properly with luting. The operation is always tedious; and some practice is always necessary before one can succeed in luting accurately." The lutes were covered with strips of bladder or linen dipped in glue, made fast with cord and allowed to dry before commencing the experiment. It is not surprising that indiarubber was adopted almost as soon as it became available. The use of caoutchouc connecting-pieces was first described by Berzelius in 1814, in connection with his method of ultimate organic analysis. He says: "I take a thin piece of [unvulcanized] caoutchouc, and heat it a little. I bend it and cut off from the bendings a small portion with a pair of scissors. The cut surfaces unite together, and form a tube. If they do not unite, let them be pressed with the nails against each other, taking care not to touch them with the fingers." In his *Chemical Manipulation*, 1827, Faraday remarks: "Caoutchouc connecting pieces are easily made, and are of such constant use in attaching tubes and apparatus for the conveyance of vapors and gases, that a number of them, from an inch to two inches long, and from a quarter to half an inch in diameter, should be kept ready. . . . They are most easily made of the sheet caoutchouc, prepared by Mr. Hancock, which is about the tenth of an inch thick, and may be had in pieces ten or twelve inches square. A piece of this caoutchouc about an inch and a half square, is to be slightly warmed until it becomes flexible and soft, and then put round a glass rod or other cylindrical body, rather smaller than the intended tube; the projecting edges are to be pinched together, and when they have slightly adhered, cut through with a pair of sharp scissors; this will . . . leave the two edges slightly adhering together. The junction is to be completed by immediately bringing these edges into contact throughout the whole extent of the cut surface . . . by applying a thumb-nail. When firmly pressed together while warm, the adhesion is such that the tube will tear elsewhere as readily as at the junction. . . . They are frequently useful of a conical form." A patent for an apparatus for squirting gutta-percha or other plastic material through an annular opening for the purpose of making continuous tubing was granted to Hunt in 1850. Soon after rubber tubing appears to have been adopted for chemical purposes, though this was probably made from cut sheet. The first reference to such use occurs in Abel and Bloxam's *Handbook of Chemistry*, 1854: "Small pieces of vulcanized Indian rubber tubing, which is now made of almost any dimensions, answer the purpose of these connectors exceedingly well; they may not adhere to the glass quite so tightly, a defect which may, however, be remedied by tying them firmly upon the tubes at each extremity." But the old form was not easily superseded, and in 1857 we find in Greville William's *Handbook of Chemical Manipulations* "Vulcanized India-rubber tubes . . . are in almost every case preferable to those made in the laboratory from sheet caoutchouc; but those which are used to connect the chloride of calcium tube with the potash bulbs in organic analysis are much better of the latter kind. The reason is that the vulcanized ones are less adhesive."

In 1844 Hancock patented a process for molding stoppers of gutta-percha, or gutta-percha and caoutchouc. But rubber stoppers for chemical purposes do not seem to have come into use until about 1865. The introduction may be attributed to Sir William Perkin. Mr. Tutin relates, on personal authority, that, impressed with the unsuitability of ordinary corks for organic analysis, Sir William was walking one day in London, when he happened to see a block of rubber in a shop window. The idea occurred to him of cutting stoppers of rubber, and was put into execution forthwith. A reference to their use appears in 1872 in the *Chemical News*, where Donkin advocates dipping the knife or cork-borer in solution of caustic potash when desiring to cut or bore indiarubber corks.

Natural rubber is obtained from the latex by a process of coalization apparently depending on the coagulation of the protein, or other protective colloid. The coagulation is brought about by heat, by the addition of acids, generally acetic, and by other methods. The globules of rubber rise through the liquid, coalesce and yield a tough elastic mass, which may be regarded as an emulsoid gel. Raw rubber contains as its principal constituent a hydrocarbon of the composition $C_{10}H_{16}$, the amount of which may reach as much as 95 per cent. Much early work was done on the destructive distillation of rubber from the time of Dalton. Its empirical constitution was determined from analyses made by Faraday, Berzelius, Ure and others. The first important chemical research on this subject was made by Greville Williams in 1860. He distilled rubber in an iron vessel at a low temperature, and obtained isoprene, C_5H_8, and cautchine, $C_{10}H_{16}$, which latter substance Wallach subsequently showed to be identical with dipentine. Greville Williams also noticed the transformation of isoprène into a rubber-like body, of which the quantity was insufficient for identification, but he evidently considered caoutchouc to be a polymer of isoprene. In 1875 Bouchardat investigated the products of the distillation of rubber, and came to the conclusion that the substances he obtained, $C_{10}H_{16}$, $C_{15}H_{24}$, etc., including rubber itself, are polymers of isoprene. In 1879, while preparing the hydrochloride of isoprene, by shaking with concentrated hydrochloric acid, a rise of temperature indicated that combination had occurred, but on distillation a solid residue remained which was found to have "the elasticity and other properties of rubber itself."

In 1882 Tilden showed that the colorless syrupy substance resulting from the atmospheric oxidation of isoprene is converted into true rubber when brought into contact with strong aqueous hydrochloric acid, or nitrosyl chloride, remarking that "It is this character of isoprene which gives it a somewhat practical interest, for, if it were possible to obtain this hydrocarbon from some other and more accessible source, the synthetic production of rubber could be accomplished." At the same time Tilden proposed the constitutional formula for isoprene, $CH_2 : C(CH_3) . CH : CH_2$. Two years later he showed that isoprene can be obtained by the destructive distillation of turpentine, indicating the first possible process for the commercial preparation of rubber. He noted that polymerisation took

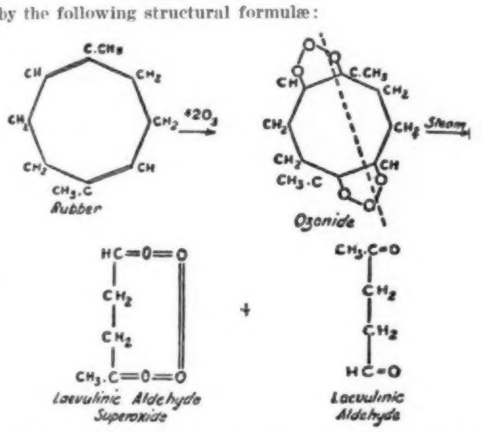
*Reprinted from *Science Progress* (London).

place most readily after a preliminary heating which yielded an oily body, and suggested that the analogues of isoprene, C_6H_8, C_6H_{10}, etc., might be made to polymerise to a series of rubber hydrocarbons. In 1887 Wallach showed that isoprene changed to a rubber-like body under the action of light alone, thereby anticipating Tilden's independent discovery five years later. In a paper published in 1892 Tilden remarks: "I was surprised . . . at finding the bottles containing isoprene from turpentine entirely changed in appearance. In place of a limpid, colorless liquid, the bottles contained a dense syrup in which were floating several large masses of solid, of a yellowish color. Upon examination this turned out to be indiarubber. . . . The artificial rubber unites with sulphur in the same way as ordinary rubber, forming a tough elastic compound." Tilden was thus the first to show that synthetic rubber can be vulcanized like natural caoutchouc. Tilden's and Bouchardat's work was confirmed by Weber in 1894, so that the scepticism expressed by Klages and Harries as to the methods employed, and the identity of the product obtained, is remarkable.

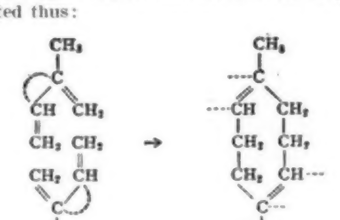
The constitution of rubber has been considerably elucidated by the extensive researches of Harries, dating from 1901 and onwards. He had found that when unsaturated substances were treated with ozone, a molecule of ozone added itself at each double bond, yielding an ozonide, which, on treatment with steam, split up into two fractions at the point of addition. In this way he determined the constitution of oleic acid. From rubber he obtained a body of the molecular weight indicated by the formula $C_{10}H_{16}O_6$. This was decomposed by steam into lævulinic aldehyde, $CH_3 . CO . CH_2 . CH_2 . CHO$, lævulinic acid, $CH_3 . CO . CH_2 . CH_2 . COOH$, and lævulinic aldehyde superoxide, $CH_3 . CO . CH_2 . CH_2 . CHO$. Harries explained the action

O——————O

by the following structural formulæ:



This indicates that the rubber nucleus is an eight-membered ring. And its formation from isoprene is represented thus:



The dotted lines denote partial valencies according to Thiele's theory. And Harries supposed that an indefinite number of rings might be linked together at the double bonds. This view was criticised by Pickles in 1910, who preferred to think that the C_5H_8 nuclei unite to form long chains as:

$$-CH_2.\overset{CH_3}{\overset{|}{C}}:CH.(CH_2)_2.\overset{CH_3}{\overset{|}{C}}:CH\ (CH_2)_2.\overset{CH_3}{\overset{|}{C}}:CH.CH_2-$$

In 1914 Harries proposed a new formula for rubber consisting of five C_5H_8 groups united to form a C_{25} ring. Rubber forms a number of addition compounds with the halogens, sulphur, etc. The simplest and most definite of these is the tetrabromide, $C_{10}H_{16}Br_4$, in which two atoms of bromine have attached themselves at each double bond. The sulphur derivatives are obtained in the process of vulcanization. Weber concluded that there is a series of sulphur compounds between the limits $(C_{10}H_{16})_{10}S_2$ and $C_{10}H_{16}S_2$, the latter corresponding to ebonite, though later work has thrown considerable doubt on the accuracy of his deductions.

The determination of the molecular weight of caoutchouc has not so far been accomplished. In the liquids usually employed to dissolve it, rubber is present in the colloidal state, and each particle probably consists of a large aggregate of molecules. So that osmotic pressure, freezing point and boiling point methods are inapplicable. As, however, in 1912 Walden discovered that starch formed a true solution in formamide, with the aid of which he found the molecular weight to correspond to the comparatively simple formula $(C_6H_{10}O_5)_n$, a true solution of rubber may eventually be obtained. In the meantime, as its simpler soluble derivatives have only ten carbon atoms in the molecule, it may be assumed that rubber contains no more than this number. That the molecules of caoutchouc and those of many of its derivatives are associated with each other to a high degree is in accordance with their colloidal condition.

From 1907 onwards the attention of a number of chemists began to be directed to the problem of the artificial production of rubber. Activity in this country was centered in the Synthetic Products Company, while in Germany the question was taken up by the Bayer Company and the Bädische Anilin und Soda Fabrik. Previous observations had shown that the homologues of isoprene polymerise to substances related to caoutchouc possessing properties varying from sticky resin to brittle solids. So far as the consumer is concerned, the exact constitution of a body is unimportant, provided its physical properties are suitable. So that the product required is not necessarily true rubber, but a substance having similar physical properties. The more important members of the isoprene series that have been considered are: erythrene, or buta-1 : 3-diene, $CH_2 : CH . CH : CH_2$; piperylene, or 1-methyl-buta-1 : 3-diene, $CH(CH_3) : CH . CH : CH_2$; and isoprene, or 2-methyl-buta-1 : 3-diene. Many methods for the preparation of these bodies have been suggested. Turpentine was originally proposed as the raw material, but, owing to its limited supply and frequent fluctuations in price, attention was directed to other substances, such as wood, starch, sugar, acetylene, coal-tar and petroleum. In 1910 the Synthetic Products Company patented a method of preparing isoprene from fusel oil. The fraction distilling at 128°–131° consists of iso-amyl alcohol, $(CH_3)_2 : CH . CH_2 . CH_2OH$, and active amyl alcohol, $CH_3 . CH_2 . CH(CH_3) . CH_2OH$, which are converted into their monochlorides with hydrochloric acid, and then chlorinated in such a way that only dichlorides result, such as $(CH_3)_2CH\ CHCl\ CH_2Cl$, $(CH_3)_2\ CCl . CH_2 . CH_2Cl$ and $\begin{matrix}CH_2Cl\\CH_3\end{matrix}\!\!>CH . CH_2 . CH_2Cl$. These are passed over soda-lime at 470°, giving a 40 per cent. yield of isoprene. As the amount of fusel oil available is small, Fernbach and Stange endeavored to devise a means for its production in larger quantities. And in 1911 they patented a method involving the cheap production of butyl alcohol and acetone by the fermentation of starch with the aid of the butylic bacillus. Butyl Chloride obtained from the alcohol is then carefully chlorinated with the production of the dichlorides $CH_3.CH_2.CHCl.CH_2Cl$, $CH_3.CHCl.CH_2.CH_2Cl$ and $CH_2Cl.CH_2.CH_2.CH_2Cl$ which yield butadiene on passing over heated soda lime.

Various means have been proposed for the polymerization of the hydrocarbons obtained. In 1909 the Bayer Company employed the application of heat to the substance contained in sealed tubes. The following year Harries found that the presence of acetic acid accelerated the change. The Bayer Company showed that the acetic acid probably acted as a diluent. And the use of other agents such as alkalies, alkaline earths, urea, blood, etc., with or without preliminary heating, have been suggested.

The most dramatic incident in the race between the English and German firms was the almost simultaneous discovery of the value of sodium as a polymerizing agent. Harries found, at the end of 1910, that sodium causes the change to take place quickly, and practically quantitatively, at a low temperature. The method was patented by the Bayer Company early in 1911. Dr. Matthews had, however, been investigating the action of sodium on dimethyl-allene, and in July, 1910, it occurred to him to seal up some isoprene with sodium. Reluctantly returning to town during a holiday in August, he discovered that the tube contained a portion of remarkably good rubber. By September the contents had set to a solid amber-colored mass. Further work indicated the importance of sodium as a general polymerizing agent for these hydrocarbons, and a patent was applied for on October 25, three months before the German application.

While possessing the same physical properties as synthetic rubbers produced by other methods, the rubbers obtained by the action of sodium appear to have a somewhat different chemical constitution. Ozonides are formed less readily, and give rise to other products than lævulinic acid and aldehyde. The constitution of sodium isourene caoutchouc is believed to be dimethylcycloöctadiene with conjugated ethylenic linkages.

A New Theory of Jupiter's Satellites

Prof. W. de Sitter has published in the *Annals of the Leiden Observatory*, 1918, xii, part 1, the outlines of an important new mathematical theory of Jupiter's satellites. A much abridged summary is also given in *K. Akad. Amsterdam, Proc.*, 1289, 1918, xx. The principal difficulty in the theory of the four old satellites of Jupiter arises from the fact that the mean motions of the three inner satellites are commensurable. The mean motion of the fourth satellite is not commensurable with those of the others, and its theory does not present any particular difficulties, in so far as the periodic inequalities are concerned; it is similar to but simpler than the lunar theory, for the ratio of the month and year is only about 1/260. The secular perturbations of the center are, however, intimately connected for the four satellites, so that it is impossible to separate them, and the apparently simple and obvious course of having one theory for the three inner satellites and another theory for the fourth cannot be adopted.

In the old theory of the motion of the satellites, the undisturbed Keplerian eclipses are taken as intermediary orbits for the four satellites, and from these orbits by the addition of perturbations and variations, the complete solution is derived. This method of procedure is the best in the case of the fourth satellite, but not for the inner three. The new theory of de Sitter is chosen so as to be the best for the case of the inner satellites, and this more than compensates for the somewhat increased difficulties in the case of the fourth satellite.

The motion of the satellites can be described as a uniform motion in a circle with superposed inequalities. The inequalities in longitude and radius-vector can be classfied according to period into four separate groups: (1) Short-period inequalities with periods not exceeding seventeen days, and including the "equations of the center" and the "great inequalities;" (2) Inequalities with periods between 400 and 5500 days: these inequalities are negligible in the radius-vector and are zero for the fourth satellite; (3) Librations of the inner satellites with a period of about seven years; (4) Long-period inequalities with periods longer than twelve years. The "great inequalities" and those of groups (2) and (3) arise through the commensurability of the mean motions and in the usual theory have small divisors.

In the new theory, intermediary orbits are used in which the expressions for the mean longitudes, mean anomalies, and lonbitudes of the perijoves of the satellites are riporously satisfied. The special features which make this solution a good first approximation in the case of the three inner satellites are the moving perijove and the fact that the induced equations of the tenter or "great ineaqualities" are larger than the free or ordinary equations. For the fourth satellite the free eccentricity is larger than the induced.

In the new theory the equations of the center are treated in much the same way as in the usual theory, but the great inequalities are not treated as perturbations, since they are of the first order. The intermediary orbit is not periodic, but contains only the principal terms of the periodic solution: to form the complete solution from this orbit are added perturbations arising from those parts of the perturbative function which were originally neglected and variations due to the fact that the actual constants of integration do not exactly fulfil the conditions of the intermediary orbit. With this method of treatment, the small divisors which arise in the old theory are avoided; they enter the equations of condition of the intermediary orbit, but do not reappear after these have been solved.

The publications referred to above treat of the theory of the longitudes and radii-vectores; the theory of the latitudes is to be treated in detail in the second part of the volume.

In connection with the derivation of the potential function an interesting point is noted. Certain terms were neglected by Laplace which contain a small factor whose value is dependent on the form of Jupiter and the distribution of its mass, but which there was then no means of evaluating. Similar terms were neglected in the complementary part of the perturbative function. The neglect of these terms was justifiable in view of the limit of accuracy which Laplace had set himself. Subsequent writers, however, have copied Laplace's perturbative function, neglecting the terms in question, although in the development of other terms quantities of the same or higher order of smallness have been included. The supposed degree of accuracy has therefore not been obtained.

Experimental Wireless Telegraphy and Telephony—III*

Simple Receiving Apparatus and Elementary Circuits for the Beginner in the Art

By Louis Gerard Pacent and Austin C. Lescarboura

(Continued from Scientific American Supplement, July 26, 1919 No. 2273, Page 53)

Perhaps it would be more logical to start with a description of transmitters and their operation, rather than the receiving end. Obviously, wireless waves start at the transmitter, and there is little use speaking about the receiving set until one knows how to generate and propagate the waves. Theoretically, that is true; but in practice there are many amateurs and experimenters who never go beyond the mere reception of radio messages and time signals, hence it is well to deal first with the side of the subject which interests everyone, namely, receiving. It is well to mention here that any radio receiving set which receives wireless telegraph signals is ready to receive wireless telephone signals; in other words there is no difference between wireless telegraph and wireless telephone waves so far as their reception is concerned.

GENERAL PRINCIPLES OF WIRELESS RECEPTION.

Receiving sets are divided into two general classes, those for damped or non-persistent waves, and those for undamped or persistent waves. Sets for damped waves in practice involve the simpler connections and form a good starting point for the discussion, although it will be shown later in introducing undamped wave sets, that a very slight modification of the damped wave apparatus will give one method of receiving undamped waves. Damped waves are commonly received by a crystal detector or a vacuum tube detector, which will be described later on, and a telephone receiver, in conjunction with suitable tuning devices. The tone heard in the telephone is that of the groups

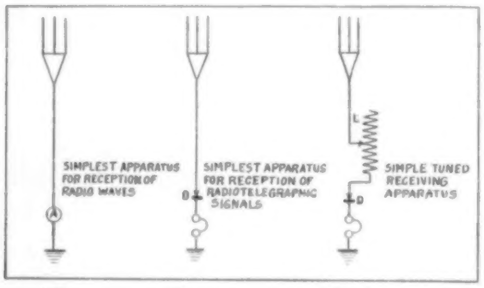


Fig. 1 Fig. 2 Fig. 3
Simplest forms of wireless receiving sets

of damped waves or the spark frequency or wave trains, already described in this series.

If a spark coil is used at the transmitting end and use is made of a slow magnetic interrupter, of the type used early in the radio art, the note received at the receiving end will be low and unpleasant to the human ear. If the interrupter is adjusted so as to give a greater number of magnetic breaks per second, the note at the receiving end increases in pitch to a corresponding degree. The low harsh notes, besides being very unpleasant to the ear of the receiving operator, are undesirable because of the similarity which they bear to static disturbances. Indeed, when using low pitched signals the operator at the receiving end is often apt to confound static for signals. Modern damped wave transmitters, however, employ a high spark frequency of approximately 500 cycles, which, besides being pleasant to the ear of the receiving operator, is readily read through atmospherics or static disturbances.

Undamped waves are ordinarily received by a vacuum tube method which produces local current more or less out of phase with the incoming signals, this difference resulting in a current which sets up audible tones known as "beats" in the telephone receiver. There are other methods of receiving undamped waves which will be described later.

The fundamental principle of reception of signals is that of resonance, or what we have already referred to as tuning. If the receiving circuits are tuned to oscillate at the same natural frequency as the incoming waves, then these waves, though extremely feeble, will, after a few impulses, build up comparatively big oscillations in the circuit. Electromagnetic waves have the power of exciting oscillations or inducing a certain amount of energy in any conductor on which they happen to impinge. This high frequency oscillating energy is usually too small to make its presence known, were it not for the aid of a suitable detector.

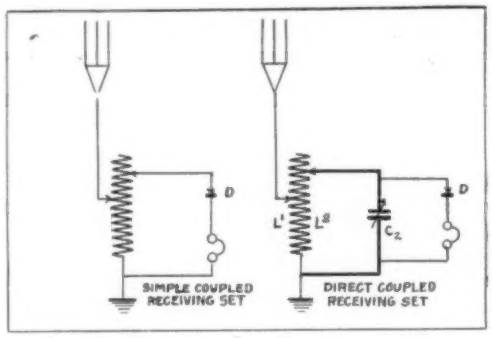
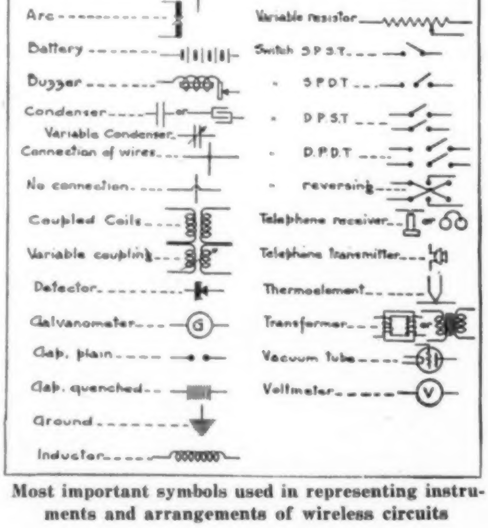


Fig. 4 Fig. 5
Two arrangements for coupled sets

In reality, then, for the reception of signals all that is needed is an antenna circuit tuned to the same wave-length as that of the transmitting station, and an instrument capable of evidencing the current which flows in the antenna connecting wire. The first sketch in the accompanying group of receiving arrangements represents the simplest possible type of receiver, and will operate on either damped or undamped waves. A current-indicating instrument is shown at *A*. In practice the current is too feeble for any hot-wire or thermo ammeter. An ammeter is more suitable for quantitative measurements than for receiving telegraphic signals, since the dots and dashes are not readily distinguished unless made so slowly as to be impracticable for transmitting purposes.

A more sensitive receiving device is a telephone receiver having a large number of turns of wire compactly wound. The current is made known by vibrations of the diaphragm at audible frequency, but the frequency of a radio current is so high that the diaphragm cannot possibly follow it. The effect is as if the diaphragm tried to go both ways at once, with the result that no observable motion takes place. To remove this difficulty a crystal rectifier is put into the circuit, which permits current to flow in one direction, but not in the other; or more exactly, the current in the reverse direction is negligibly small compared with the current in the principal direction. This action was described in the first part of this series.



Most important symbols used in representing instruments and arrangements of wireless circuits

It is found that the cumulative effect of one group of train waves, for instance that due to one condenser discharge at the transmitter, pulls the telephone diaphragm away from its neutral position. The number of such pulls per second is equal to the number of wave trains per second. With a 300-meter wave having 1,000 wave trains per second the radio frequency is 1,000,000 and the audio frequency is 1,000 or one is a thousand times as high as the other. The upper limit of audio frequency for the human ear is 16,000 to 20,000 sound waves per second, so that even if the telephone diaphragm could, with a rectifier, follow the radio frequency, the ear would not hear the signals. In telegraphic signalling, either a dot or a dash lasts long enough to contain many wave groups, and in the telephone, where the pitch corresponds to the spark frequency, a tone is heard during the length of the dot or dash.

SIMPLE RECEIVING SETS.

The second sketch of the group shows the simplest connection for receiving signals with a telephone receiver. It is suitable only for damped waves. At *D* is shown the rectifier, commonly called a detector, although it detects nothing; it simply alters the waves so that the telephone can detect them. The apparatus as shown receives best from a transmitter of the same, or nearly the same, wave-length. It is true that the presence of the detector and telephone introduces high resistance in the antenna circuit and thus renders it not very selective, so that it will respond to a wide range of wave-lengths. Tuning to resonance is made

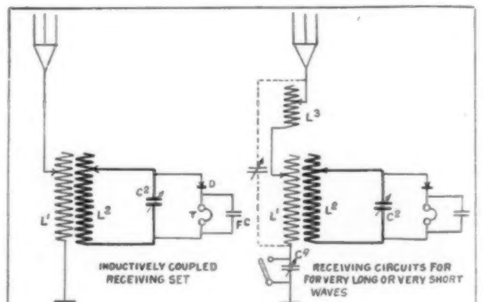


Fig. 6 Fig. 7
Inductively coupled receivers

possible if a tuning coil is introduced such as *L* in the third sketch, to vary the inductance of the circuit and hence the wave-length. Thus it becomes possible to receive signals of any wave-length, by merely varying the number of turns of wire introduced in the antenna circuit by the tuning coil.

It is well to notice how simple is the apparatus actually needed for reception, contrary to what the uninitiated person supposes. Three pieces of apparatus—telephone receiver, rectifier or detector, and tuning coil—will receive effectively from damped wave stations. The main disadvantage of such a simple set, however, is in not being able to tune out stations that one does not wish to hear. Also the amplitude of the oscillation is much diminished by the high resistance of the detector and telephone. The principal resistance is that of the detector.

The apparatus shown in the third sketch gives practically the same results if the telephone is in shunt with the detector, instead of in series with it. In this case the explanation of the action is as follows: Suppose that the current flows easily upward through the rectifier, but not downward. During a group of incoming waves, the antenna thus receives an accumulated positive charge, and during the intervals between wave groups it discharges downward through the telephone. It cannot send current downward through the telephone. The pulsations of current pass through the telephone with successive wave groups.

To avoid the difficulties attendant upon the presence of the detector in the antenna circuit, it is customary to place the detector in a separate circuit coupled to the antenna; or another viewpoint is that the detecting instruments are placed as a shunt to the tuning coil. For instance, the fourth sketch shows a decided im-

*This is the third article of the series dealing with wireless telegraphy and telephony for the beginner in the art. The first article appeared in the Scientific American Supplement No. 2270, dated July 5, 1919, and the second in No. 2273, dated July 26, 1919. Every phase of amateur radio is being covered in this series, in a simple, clear and thorough manner, together with the latest commercial practices.

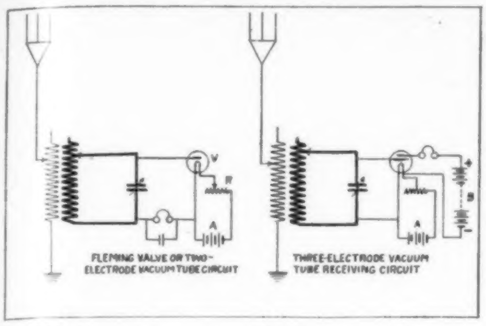


Fig. 8 Fig. 9
Simple connections for vaccum tube detectors

provement over the previous arrangement, and requires no more apparatus except that the tuning coil has two adjustable contacts or "sliders" instead of one. Oscillations now take place freely between the antenna and ground. Two telephone receivers are shown, connected in series, one for each ear.

A further improvement is shown in the fifth sketch, where a variable condenser has been added. This is called a direct coupled connection. Let L_1 be the inductance in the antenna circuit, C_1 the capacitance between the antenna and ground, L_2 and C_2 the corresponding constants in the closed circuit shown by heavy lines. The antenna circuit is called the primary, since the energy enters the set there. The circuit containing L_2 and C_2 is called the secondary and is the closed oscillating circuit. In the same manner in which the transmitting antenna circuit is a good radiator of power, so the receiving antenna circuit is a good absorber. It is tuned to resonance with the incoming waves by adjustment of L_1. The power is given over magnetically to the secondary, which is tuned to resonance by adjustment L_2 and C_2. Comparatively large oscillations result in the secondary, producing voltages across the condenser which are detected by the crystal and telephone, which are not in either oscillating circuit. The oscillations are not damped thereby, and sharp tuning is obtained.

INDUCTIVELY COUPLED RECEIVING SETS.

In the sixth sketch is shown the inductively coupled set, which is in wide use today. This may be taken as the standard upon which all later changes are based. A fixed condenser of about 0.005 mfd. is shunted around the telephone and this increases the strength of the signals. Its action is explained as follows: Suppose the principal current flows downward through the detector and telephone. While this current flows, the fixed condenser is charged with top plate positive. When the reversal of the radio oscillation comes, the current through D and T ceases. Then the condenser discharges down through T and tends to maintain the current till the next oscillation downward through the instruments. In this way the gaps between the successive pulsations of rectified current are filled in, and the cumulative effect of a wave group is strengthened. In practice the telephone cord, containing as it does two conductors separated by dielectric, forms a condenser which in some cases is sufficient so that an added fixed condenser gives no improvement.

The connections shown in this last sketch give an effect similar to the direct coupled arrangement. In either case, on account of the coupling between the primary and secondary coils, there are reactions of each coil upon the other, with consequent double oscillations when the coils are near together. Sharp tuning becomes impossible. It is found, however, that if the resistance of the circuits is low, extremely sharp tuning is obtained. The antenna is tuned to the incoming waves by changes of the inductance L_1. Sometimes, if very sharp primary tuning is desired, a variable condenser is shunted around L_1, and the fine adjustments are made therewith. The secondary is tuned to the primary, the operations of tuning being done alternately until the telephone gives the best response. In the secondary the coarser tuning is done by changes of the inductance L_2, and the fine tuning with the variable condenser C_2.

For receiving a longer wave in the primary circuit than is possible by using all of the inductance L_1 a series inductance L_3, called a loading coil, is added, as shown in the seventh sketch. Also a variable condenser may be added as per dotted lines, to increase the wave-length and afford fine tuning. The secondary may also be provided with an extra inductance in series with L_2 if needed. For receiving short waves on a large antenna, series condenser C_4 is inserted in the ground wire. It is short circuited when not in use.

In the typical sets so far described a crystal rectifier is used as the detector. The principal disadvantage of this type of detector is that it cannot be depended upon to stay in adjustment. A good deal of time is required for the frequent readjustments. The eighth sketch shows exactly the same connection, but with the crystal detector replaced by a Fleming valve, V. This is a glass bulb containing two electrodes and having the air exhausted. One electrode in the vacuum is a lamp filament which is heated by current from a storage battery A. The other electrode is a metal plate. The heated filament gives off a stream of electrons toward the plate, as will be covered in detail in a subsequent section of this series. Current from incoming electric waves can pass through the vacuum in only one direction determined by the electrons, the current in the opposite direction being suppressed. In this way the tube acts as a rectifier. It is very stable and about as sensitive as a good crystal.

A still further improvement is shown in the ninth sketch, using a vacuum tube having three electrodes. It is seen here that the circuits joined to the filament and the nearer electrode are exactly the same as in the preceding arrangement. The telephone, however, is in a circuit with a battery B, and the signals received thereby are much louder than with the Fleming valve arrangement. For the theory of action of the three-electrode vacuum tube as a detector, it is best to wait until the entire subject of vacuum tubes is taken up and thoroughly discussed later on.

Suffice it to add here that because the vacuum tube detector is a voltage-operated device—in other words, the highest potential applied on the grid will give the maximum signal in the telephone receiver—it works best with minimum capacity and maximum inductance in a circuit.

CAPACITY COUPLED RECEIVING SET.

A method of coupling receiving apparatus to the antenna circuit which affords compactness is shown in the tenth sketch. By fixing the primary and secondary coils L_1 and L_2 permanently at right angles to each other, inductive coupling between the two is prevented. Instead, the coupling between the two circuits is effected through the condensers CC_1—although usually one condenser is used—which are referred to as "coupling condensers." Such an arrangement is called "electrostatic" or "capacitive" coupling. The condensers are arranged so that by turning one handle both are varied together. One of the condensers, C_1, the one connected to earth, may be omitted, but better results are usually obtained with two. The advantages of capacitive coupling are as follows: (1) The coils are of compact form. They are wound as rings with rectangular or square winding section, thus giving large inductances in small space. This is a great saving of room compared with sets using variable inductive coupling where the coils must be so constructed that one of them can move with respect to the other, and where they are usually wound on long tubes in order to get suitable variation of coupling. (2) The coils are fixed. In the inductive type they must sometimes be separated by many inches for very loose coupling. (3) The coupling is quickly and easily changed.

A great disadvantage of the capacity coupled set, however, is that when receiving from long-distance modern sharply-tuned transmitting stations, the varying of the condenser coupling changes the wave-length of the secondary circuit and thus throws the receiving set out of resonance with the incoming signals. Time is lost in again tuning in the station. Another disadvantage is that capacity coupling cannot be used successfully on short or amateur wave-lengths for two reasons: first, the coupling condenser must be very small and the movement of the operator's hand sets the receiving equipment out of resonance, so delicate is the electrical balance; secondly, it usually proves most unstable and cannot be depended upon; thirdly, it is less efficient when employing vacuum tubes as detectors.

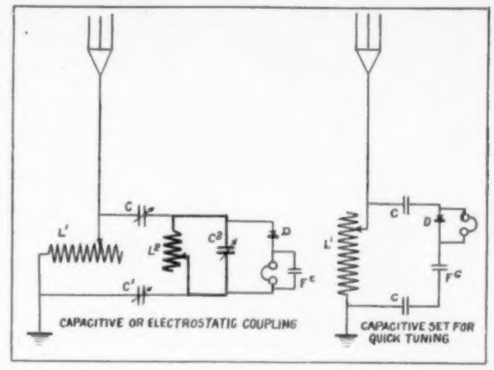


Fig. 10 Fig. 11
Wiring schemes for capacitive receivers

When simplicity of tuning is the principal requirement, and it is desired to reduce the tuning operations to a minimum number, even at the expense of a certain amount of selectivity, the following methods are used:

In the eleventh sketch is shown a modification of the capacitive connection; in practice the change from the previous connections to the simpler connections here shown are accomplished by one switch. The secondary is removed, and the telephone is put in shunt with the detector instead of with the fixed condenser FC. If a medium value of coupling is used it is not usually necessary to alter it, therefore the only tuning adjustment is that of the primary inductance.

Another device for quick-tuning is shown in the twelfth sketch. This employs an inductive coupling. The primary is tuned sharply to the incoming waves, while the secondary is untuned. With the connections as shown, the secondary will respond in practically the same manner to a wide range of wave-lengths, owing to the high resistance of the detector. The only adjustment the operator has to make is that of the primary inductance. Sometimes additional provision is made for adjustment of the coupling by separating the coils; this gives variation in the sharpness of tuning and in the signal strength.

All these methods of quick tuning are used when listening for possible calls from a number of stations, because it is convenient to have apparatus that will respond to a wide variety of wave-lengths. As soon as the desired station is heard, the operator can then switch over to the usual receiving arrangement which ensures the desired degree of selectivity.

(*Continued on page 91*)

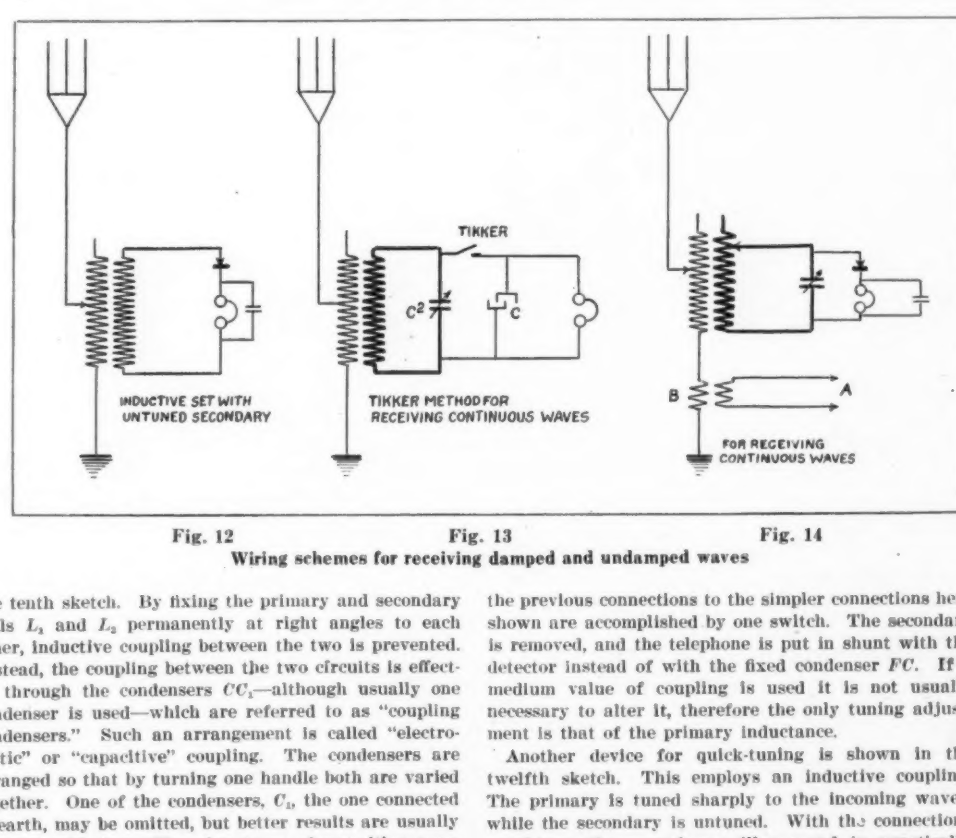


Fig. 12 Fig. 13 Fig. 14
Wiring schemes for receiving damped and undamped waves

The Law of Irreversible Evolution*

Critical Notes upon Dollo's Famous Hypothesis

By Branislav Petronievics, Ph.D.

Louis Dollo, the great Belgian palaeontologist, first formulated publicly[1] in 1893 his celebrated law of irreversible evolution, one of the most important laws governing organic evolution.[2] This law has been often discussed and applied, but so far as I know no one has attempted to make an exposition of it based upon the various works of Dollo himself. It is this task which I undertake to perform here, at the same time adding to my exposition of the law in question certain critical remarks upon its value.

The law of irreversible evolution was formulated by Dollo as follows: An organism cannot return, even partially, to an anterior state previously attained in the series of its ancestors.[3]

The commonly accepted view is that the law thus defined relates solely to parts or to organs which have been reduced or which have disappeared, but this view is inexact. The scope of the law is far more vast, for it also embraces the functional organ.[4] In order better to understand the wide scope embraced in this law of Dollo it is necessary to make certain distinctions in the concept of organic evolution and to define it more precisely.

As we know, organic evolution may be divided into three classes, progressive, retrogressive and mixed.[5] If progression predominates in mixed evolution (which is the most wide-spread type in the realm of organic evolution), or, in other words, if the final state attained represents progress in comparison with the initial state, then we call this kind of mixed evolution ascending evolution—pure progressive evolution representing the ultimate form in this sort of evolution. But if retrogression predominates in the mixed evolution, or, in other words, if the final state attained is a throw-back in comparison with the initial state, we call such evolution descending evolution—pure retrogressive evolution evidently representing the ultimate form of this kind of evolution. The best known example of mixed ascending evolution is found in the foot of the horse, which is composed of a single digit and which was evolved from a five-toed foot by the atrophy of the lateral digits and the comparatively greater increase in size of the middle digit; an admirable example of descending mixed evolution, on the other hand, is found in the comparison of the skull of the living Ceratodus with the skull of the Dipterus, its probable ancestor in the Devonian period.

By keeping in mind the definitions just formulated, on the one hand, and on the other the examples given further on, cited by Dollo in support of his law, we shall be able to separate the cases of ascending evolution from those of descending evolution, a thing which was not done even by Dollo himself. It is evident that if the structure or the parts of an organ be lost through descending evolution, and if it is not possible, as is almost unanimously agreed, to re-establish the lost structure or the lost parts by a new ascending evolution, it nevertheless by no means follows—at any rate *à priori*—that a reversibility of the evolution might not be possible in the contrary case, i. e. when the structure of an organ has been lost through the ascending evolution of the said organ.

It is necessary, therefore, to replace the single law of Dollo by three different laws, one of which, the first and the most fundamental, shall express the impossibility of the reacquisition of the lost parts, while the second concerns those cases in which the structure of an organ has been lost through ascending evolution, and the third those cases in which the structure has been lost through descending evolution. These three laws may be expressed as follows:

1. The organs and the parts of organs which have been reduced or lost through retrogressive evolution cannot be regained by a new progressive evolution.[6]

2. If the structure of an organ has been lost through ascending evolution (with or without the addition of new parts, and with or without the loss of certain parts), then the lost structure cannot be regained: (*a*) either by the reacquisition of the lost parts, since such reacquisition is impossible in virtue of the first law; (*b*) nor by the retrogressive evolution of new parts, since the total disappearance of such parts is impossible; (*c*) nor by the ascending evolution of these new parts in a new direction.

3. If the structure of an organ has been lost through descending evolution (with or without the loss of certain parts), then the said structure cannot be regained: (*a*) either by the reacquisition and progressive evolution of the lost parts, such reacquisition being impossible according to the first law; (*b*) nor by the ascending evolution of the non-reduced parts in a new direction; (*c*) nor by the ascending evolution of the parts which are entirely new.

We will now explain the different cases falling under these three laws by examples found in the writings of Dollo.

The examples to which the first law applies are very numerous. The birds lost their teeth during the Cretaceous period; no bird of a later period was able to regain these lost parts. The jaw of the mammals consists of a single piece which is homologous to the tooth-bearing part of the reptilian ancestors, and no mammal has been able to regain the other lost parts of the reptilian jaw, etc.

These examples in which the return to the adaptation found in the ancestors would require the reappearance of the lost parts of an organism demonstrate especially well the validity of the first law; as they are also examples of the other two laws we shall expound them in connection with the latter.

The best known example of the first case under the second law is the pseudo-dentition of the Odontopteryx, a fossil bird of the Eocene period. Instead of having the true teeth, which had been lost, the Odontopteryx, has the edges of the beak and of the lower jaw toothed like the edge of a saw. The most striking example of the second case, under the second law, is the pelvis of the Triceratops. The Dinosaurian ancestors of this animal adapted themselves to living as bipeds and as such they possess a very long and very narrow ischium, and a pubis provided with a postpubis which was likewise very long and narrow.[7]

In its secondary adaptation to life as a quadruped the Triceratops was not able to regain morphologically the triradial pelvis of its remote quadruped ancestors. For it had preserved the traces of the biped phase in the rudimentary postpubis and also in the narrow and curving ischium of its pelvis; i. e. the postpubis, the new part acquired during the biped life, had not succeeded in entirely disappearing and in the same way the new form of its ischium had not been able to disappear.[8]

The most evident example, and likewise the most important, of the third case under the second law is also found in a Dinosaurian closely related to the preceding one, namely, the Stegosaurus. The immediate ancestors of this animal were bipeds like those of the Triceratops, and like the latter it readapted itself to the life of a quadruped. But while the triradial pelvis of the remote quadruped ancestors was re-established physiologically by retrogressive evolution (by means of atrophy) of the postpelvis and of the ischium in the Triceratops,[8] in the Stegosaurus these parts have undergone evolution in a new direction. Here the ischium is shortened and flattened and so is the postpubis, which, moreover, lies closely along the lengthwise ventral edge of the ischium. But from the morphological point of view neither have we here a return to the state of the triradial pelvis of the past, for the ischium has preserved some trace of the form acquired in the biped phase and the posterior branch of the pelvis is no longer constituted by the ischium alone but by the ischio-postpubian complex. By developing this new direction the postpubis has, therefore, undergone a change of function.[8]

We find an example of the first case under the third law in the evolution of arms in the octopus. The octopus in adapting themselves to the benthonic life have lost one pair of arms (the tentacular arms) of their immediate ancestors, the heteropod decapods. Thus they have become isopods once more (apart from the exceptional case of the Argonaut and the hectocotylization of one of their arms) like their remote ancestors the Belemnotheutides isopods and decapods), without having been able to regain the same number of arms.[9]

The most important example of the second case of the third law is the foot of the Dendrolagus, a tree-living kangaroo. The structure of the foot of the jumping macropods—the predominance of the fourth toe, the syndactylism of the second and the third, the reduction of the fifth, and the total disappearance of the great toe, shows us that their immediate ancestors were arboreal. In the Dendrolagus, a macropod which became arboreal once more, the great toe capable of being opposed to the other toe, like the thumb in the hand of man, which was entirely atrophied in its immediate ancestors, the terrestrial kangaroos, was not able to reappear, but the non-reduced parts underwent an ascending evolution in a new direction. While the metatarsals and the phalanges have diminished in length, the phalangines, the phalangettes and the claws are elongated and the latter are also curved. Thus the foot of the Dendrolagus has not been able to revert to the structure of the foot of its remote tree climbing ancestors which possessed an opposable great toe, a united second and third toe, a predominant fourth toe, and reduced claws.[10]

Finally, we have as an example of the third case, under the third law, the secondary carapaces and plastrons of the Dermochelys turtle. The remote ancestors of this turtle were marine turtles, like itself; its reduced primary plastron (a ring composed of four pieces) and its still more reduced primary carapace (represented by the single nuchal plate) bear witness to this. In adapting themselves to shore life the immediate ancestors of the Dermochelys regained a carapace and a plastron, but this carapace and this plastron are parts of entirely new superficial dermal origin. In readapting itself to marine life the Dermochelys has preserved this athecous plastron and carapace of its immediate ancestors, although both are already considerably reduced.[11]

The importance of the law of irreversible evolution is manifold. In the first place it possesses a phylogenic application, i. e. it enables us to reconstitute with the very often insufficient paleontological material at our disposal, if not the actual phylogenic series, at any rate, series representing incontestable stages of evolution. Its ethological application is still more important, for it is often the only means by which we can determine the conditions of existence under

*Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from an article in French, in *Science Progress* (London).

[1]Dollo, The Laws of Evolution; Bulletin of the Belgian Society of Geol., etc.; VII., 1893, pp. 164-6.

[2]He had already announced this law in 1892 in his lectures upon the evolution of the vertebrate skeleton, at the Solvay Institute, University of Brussels; also in a note in the Bulletin mentioned in note 1.

[3] l. c. Note 1. Later he phrased the law with even more precision: "An organism never resumes an anterior state precisely, even when placed in conditions of existence precisely identical with those previously traversed. But in view of the indestructibility of the past it always retains some trace of the intermediate stages through which it has passed." In this connection it should be noted that he expressly admits the reversibility of the conditions of existence: "Evolution is irreversible with respect to the structure of organisms, but reversible as regards conditions of existence."

[4]Dollo, Ethological Paleontology, Bull. Soc. Geol., XXIII., 1909, notes, pp. 377-421. Refer especially to remark 2, p. 400.

[5]In my open course on universal evolution at the Sorbonne for the present year, which will be published later, I have defined evolution in general in the following manner: "Evolution is the formation of a thing by means of successive degrees of change." When each successive state in the progress of evolution contains something more than the preceding state the evolution is progressive, and it is regressive when each successive state contains something less than the preceding one. It is mixed when in a complete organism undergoing evolution, one part evolves progressively and another part regressively.

[6]For the first law see Dollo, On the Origin of the Luth Turtle (*Dermochelys Coriacea*), Bull. Roy. Soc. Med. and Nat. Sci. of Brussels, 1901, pp. 1-26; A New Tympanic Opercule of Pliopiatecarpus (*Mosasaurian Diver*), Bull. Belg. Soc. Geol., XIX., 1905, pp. 125-131; and the reference of note 4.

[7]Dollo, The Dinosaurians Adapted to the Secondary Quadrupedal Life, Bull. Belg. Soc. Geol., XIX., 1905, pp. 441-8.

[8]l. c. note 7, p. 446, 447.

[9]Dollo, The Cephalopods Adapted to the Secondary Necteric Life and to the Tertiary Benthonic Life, Zoolog. Jahrbucher, Supp. Vol. XV., 1912, pp. 105-140. A still more convincing example would be the secondary stegocephalism of the Chelonia. This is distinguished from the primary stegocephalism of the ancestral stegocephalic amphibians by the fact that the postorbital, the supratemporal and the epiotic, when once lost, do not appear again in the cranial vault; Dollo, *Podocnemis Congolensis* and the Evolution of the Fluviatile Chelonia, Annales du Musee du Congo-Belge, Brussels, 1913, pp. 49-65. But the secondary stegocephalism of the Chelonia, although very probable, is not yet established beyond a doubt—see particularly the recent note by G. A. Boulenger, The Position of the Chelonia in Classification, *Comt. Rend.*, Vol. 167, 1918, p. 514. See also D. M. S. Watson, *Eunotosaurus Africanus, Proc. Zool. Soc.*, London, 1917, p. 10-11 ff.

[10]Dollo, Did the Ancestors of the Marsupials Live in Trees? Biological Miscellanea, Paris, 1899, pp. 188-203.

[11]See first reference of note 6, pp. 9-14.

which fossil organisms lived and the method of their adaptation to such life. But this law sometimes possesses a morphological importance also, since by making use of it we are able to distinguish true homologies from simple analogies. Finally, Dollo demonstrated that it could be made to serve also as a guide in classification, and, therefore, that it also possesses a systematic application.

The most important phylogenic application of the law was made by Dollo in the difficult question of the phylogeny of the Dipneusts, and his extremely ingenious note upon this question must be regarded as a model of philosophic intelligence in the new paleontology. Before Dollo this question was in a truly chaotic state, one of the most eminent paleontologists having declared the Dipterus, the most ancient and the most primitive type, to be the most highly specialized type![12] Nowhere has the idea of the irreversibility of evolution given such brilliant results as here. Since this idea formulates the law that there is never a complete return to an ancestral structure, it can be employed to determine whether an arrangement is primary or secondary, and consequently, when we have a series possessing a sufficient number of intermediate terms between the first and the last term, also to determine the direction of the evolution.[13] But we do possess such a series in the paleontological series of the Dipneusts: ***Dipterus Valenciennesi, Dipterus macropterus, Scaumenacia, Phaneropleuron, Uronemus, Ctenodus, Ceratodus, Protopterus, Lepidosiren.***[14] Dollo shows us that the structure of the tail as well as that of the top of the head, the scale formation, the jugular plates, the opercular apparatus, the ganoin and the ossification of the mandible, and finally the sub-orbital band, all bear witness to the fact that progress is made in the direction proceeding from Dipterus to Ceratodus and not in the opposite direction.[15] It is in the structure of the tail in particular that the idea of irreversibility becomes evident. In a long and learned discussion Dollo proves[16] that the diphycercal tail of the Dipneusts (and of other known ancient and modern fishes) is a secondary one, whose morphological value in the Dipneusts, consisting as it does of the second dorsal fin plus the second anal fin, is not equivalent to the morphological value of the primitive diphycercal tail (the caudal fin). Obviously, therefore, there is no return to the primitive structure in this secondary diphycercia.[17]

The most important other cases of phylogeny discussed by Dollo are the phylogeny of the Sirenians, of the Luth turtle and of the Holocephales.

One of the most important cases as regards the ethological application of the law of irreversibility is also found in the note on the phylogeny of the Dipneusts. If we supposed the Dipterus to be derived from the Ceratodus, since the latter is an adaptation to life in polluted water, then it would be necessary to suppose either that Dipterus represents an adaptation to life in the mud (intensified muddy water), or else that it represents a return to life in clear water. The first case being that of the Lepidosiren only the second remains to be discussed.[18] But, aside from paleontological reasons and those which are purely ethological,[19] the law of the irreversibility of evolution is exactly opposed to this. For "is the lost ganoine recovered? Does the cephalic shield resolve itself into its ancestral element? Will the suborbital fibrous band with its variable number of bonelefs again form a continuous arch? Will the opercular apparatus resume its first dimensions? Will the vanished jugular plates reappear?" Since all these things are reduced in the Ceratodus[19] it is obvious that the Dipterus can only represent a primary adaptation to life in clear water, i. e. that it is a genuine fish ("the most piscatory form of Dipneusts").[20]

Another important case of the ethological application is the biped life of the immediate ancestors of the Stegosaurus and of the Triceratops. For "if the evolution were reversible these two Dinosaurians would have regained the exact quadruped form which they had previously possessed, and we should not have been able to distinguish their secondary from their primary quadruped life."[21]

The other important cases of ethological applications are the secondary adaptations to the necteric life of the Pycnodonts,[22] the Trilobites Deiphon and Aeglina, etc.

Among the cases of morphological application those of the secondary abdominal ventral fins in the Teleostians possess a special importance. As we know, the ventrals of these creatures can be either abdominal, thoracic or jugular. But among the abdominal ventrals there are two classes: Those which have absolutely no connection with the scapular band and those which are connected with the clavicular symphysis by a ligament. As there is no reason for the existence of this ligament *in situ* we are bound to suppose that it is the degenerated remainder of a former direct connection with the scapularband. Conformably to the law of the irreversibility of evolution the ventrals have become abdominal again, but they have retained their former thoracic or jugular connection with the clavicular symphysis.[23] The other important cases of the morphological application are: The remotely anterior choanae shown in the marine Chelonians[24] and the longirostria and brevirostria of the Crocodiles.[25]

Finally, it is necessary to mention also the single case in which Dollo made a systematic application of his law, that of the Ptyctodontes. Previous to Dollo these fossil fishes, known up to that time only by dentary plates, were classified among the Holocephales. In his important notes upon this subject[26] Dollo has shown in supporting his reasoning by the law of irreversible evolution, that the Ptyctodontes cannot be considered properly as Holocephales but must be regarded as Arthrodera. Since then this conclusion has been fully confirmed. Although the empirical evidence of the validity of his law has been numerous and varied Dollo has not contented himself with purely empirical demonstration. He has attempted also to give a deductive demonstration. With respect to this he says:

"The irreversibility of evolution is not merely an empirical law, based solely upon observed facts, as many persons have believed, but possesses profound causes which reduce it in the last analysis to a question of probabilities, like other natural laws. Since evolution, in fact, is a summing up of perfectly definite individual variations in a perfectly definite order, then in case it were reversible it would be necessary to admit the intervention of causes exactly the opposite of those which have given rise to the individual variations, the sources of the first transformation, and to their fixation, and this in an order also exactly opposite—but these conditions are too complex to permit us to believe that they ever obtained."[27]

And in speaking of the impossibility of the descent of the Dipterus from the Ceratodus[28] he says: "And it should be observed that we are not here concerned with an isolated character, but with a whole series of characters, which is a much more serious matter with respect to irreversibility . . . but it is in the operation of elements so manifold that we are particularly able to affirm with certainty that evolution is not reversible."[28]

Thus according to Dollo the greater the number of elements the greater the probability of the irreversibility of evolution, and it becomes a practical necessity when there is a very considerable number of elements. Having expounded the law of irreversible evolution, the different cases which it explains, its applications, and its logical basis, we will now make certain critical observations concerning these different aspects of the said law.

Let us consider first its logical basis. The deductive demonstration attempted by Dollo is very dubious. As for the number of elements operative in evolution, it is not the cells which are concerned, but the organs and the parts of organs (because it is the latter alone which possesses definite arrangements in the germen) and the number of these is in comparison not very considerable even in the most complex organism. But if we take into account the much more considerable number of individuals in which the organs and the parts of organs exhibit individual variations, then the probability of their variations in different directions and consequently also in inverse directions, becomes appreciable. It is only when we affirm that the individual variations are predetermined and comparatively few that this reasoning founded upon pure probability begins to totter. But then the law of irreversible evolution would not be the result of probability based on numbers, but the result of unknown internal causes of organic evolution.

Hence there is no logical necessity in the law of irreversible evolution, and the said law rests upon a purely empirical foundation. Let us now see in how far the three laws of the said evolution are confirmed by experience and in what measure we may expect to find possible exceptions.

As for the first law it seems to present no exceptions in so far as it relates to lost parts or organs. In fact, since the loss of an organ or a part has become definite because of the loss of the corresponding arrangement in the germen, it is almost impossible to suppose that there could be a reappearance of the said arrangement, in view of the difficulty of the production of new configurations in the germen by the influence of external causes, on the one hand, and because of the degree of correlation required by these arrangements, on the other hand.[29] When the matter in question is a reduced organ or part then the two cases must be distinguished. If the said reduction has advanced so far that the corresponding configuration in the germen exhibits a tendency towards complete disappearance, then the reduced organ or the reduced part is practically as good as lost. But if their reduction has not proceeded to such an advanced stage then their evolution in the opposite direction would not be impossible.

With regard to the second law, we must distinguish the case of a single part from the case of a complex organ. It is evident that the retrogressive evolution of a single part might re-establish the point of departure of the progressive evolution provided no change of form had taken place during either the retrogressive evolution or the preceding progressive evolution. And it is evident also that the retrogressive evolution of a single part might be followed by a new progressive evolution in case the corresponding arrangement in the germen were not too greatly weakened. But if a change of form has been effected during the first progressive evolution and if the said change of form has been so considerable as to necessitate a corresponding change in the configuration of the germen, then neither the retrogressive evolution following the first progressive evolution can re-establish the point of departure of the latter nor can a new progressive evolution succeed in doing this, since this would require the reversion to a configuration which has disappeared. If, for example, a tooth first increased in size and then diminished without any change of form, then this tooth might so diminish as to resume the dimensions it possessed at the beginning of its increase in size, and a new increase of the same form would not be impossible provided the reduction had not proceeded too far. But if the growth in size had been accompanied by a radical change of form, if, for example, a conical tooth had become compressed laterally, then a return to the conical form would not be possible, either during its diminution in size[30] nor during a new increase in size.

When a complex organ is concerned Dollo affirms that its reversion to an anterior state by means of retrogressive evolution is not possible because of what he calls "the indestructibility of the past." But if a single reduced part of an organ be made the pretended reason of the irreversibility then it may be affirmed with almost entire certainty that in this case the indestructibility of the past does not exist, since it contradicts the well-established law of the retrogressive evolution required for the production of non-functional

(*Continued on page 95*)

[12]See A. S. Woodward, Catalogue of the Fossil Fishes in the British Museum, part II., 1891, p. 20. But after the publication of Dollo's important memoir, Woodward accepted the latter's conclusion; see his presidential address to the Section on Geology, Nature, Vol. 81, 1909, p. 292, and Dollo, reference of note 4, remark 2, p. 387.

[13]Dollo, On the Phylogeny of the Dipneusts, Bull. Belg. Soc. Geol., IX., 1895, pp. 79-128. In treating the question of the phylogeny of the Holocephales, Dollo (The Ptyctodonts Belong to the Arthrodera, Bull. Belg. Soc. Geol., XXI., 1907, pp. 97-108) says: "The idea of the irreversibility of evolution—which led me to the conclusion that I have just attempted to justify—has once more proved its utility, since without this hypothesis we should be obliged to hold that specialized organisms may become primitive once more and then become specialized anew, either in the same or in a different direction. But this is a process which—at least in our present unwillingness to dispose absolutely of complete paleontological series—would destroy every possibility of arriving at the phylogeny: and this is the supreme object of the science of morphology.

[14]Reference of note 13, p. 88.

[15]l. c., pp. 86, 87.

[16]l. c., pp. 89-97.

[17]l. c., p. 96.

[18]l. c. p. 99.

[19]l. c., p. 100.

[20]l. c., p. 101.

[21]First reference of note 9, pp. 108-9.

[22]Reference of note 4, pp. 410, 412.

[23]Dollo, The Teleostians with Secondary Abdominal Ventrals, Minutes of the K. K. Zool. and Bot. Soc. in Vienna, LIX., 1909, pp. 135-140.

[24]Dollo, On the Evolution of the Marine Chelonia (Bionomic and Phylogenic Considerations), Bull. Roy. Acad. Belg., Div. of Sci., 1903, pp. 801-850.

[25]Dollo, New Note on the Reptiles of the Lower Eocene in Belgium and Nearby Regions, Bull. Belg. Soc. Geol., XXI., 1907, pp. 81-5.

[26]Second reference of note 13.

[27]Second reference of note 9, pp. 59 ff; also Dollo, On the Morphology of Ribs, Sci. Bull. France and Belg., Paris, XXIV., 1892, pp. 113-129.

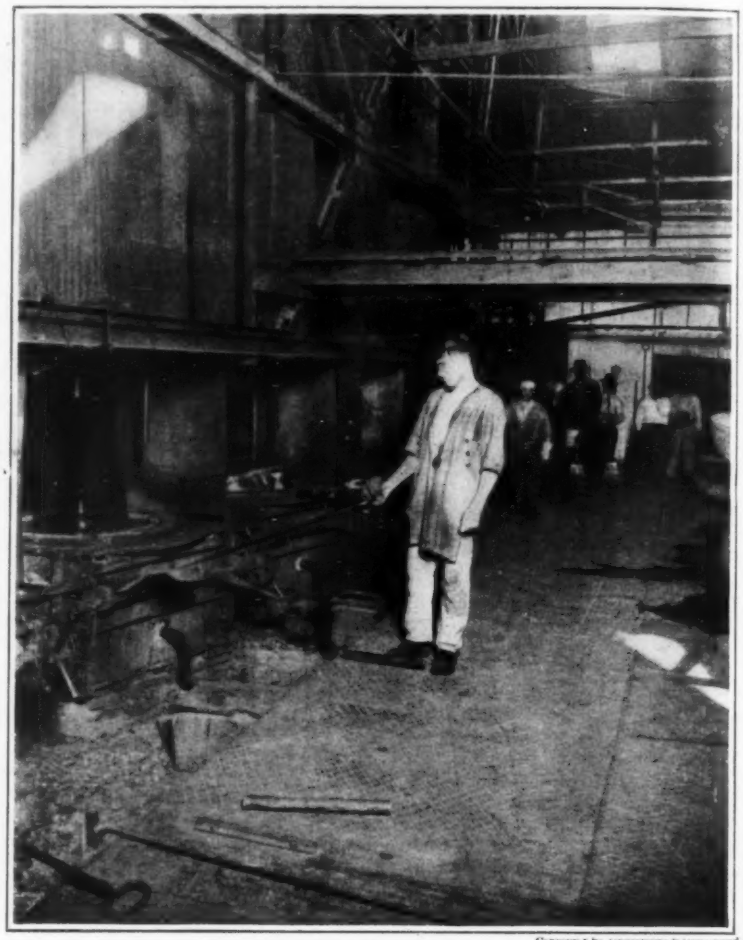
[28]Reference of note 13.

[29]Compare with similar reflections of A. Handlirsch, cited by Dollo in The Fishes that Spread Sails, Zool. Jahr., XXVII., 1909, p. 429.

[30]This impossibility is precisely what has been supposed by W. D. Matthew to have taken place during the evolution of *Felidae*, supposing that the felines are derived from the Dinictis, a primitive machaerodontous cat; see his Phylogeny of the *Felidae*, Bull. Am. Mus. Nat. Hist., XXVIII., 1910, p. 290 ff. Scott clearly perceives that this phylogeny contradicts the law of irreversible evolution.

Copyright by Underwood & Underwood

Starting a cylinder. The pipe, blown by compressed air, is in the middle and as it rises on its tracks the glass cylinder comes up out of the pot



Copyright by Underwood & Underwood

Rear view of drawing kilns; the left-hand pot is furnishing a cylinder

Window Glass*

Hand and Machine-Made Panes, and the Machines That Make Them

By John Oliver LaGorce

[Text and Photographs by courtesy of National Geographic Society]

CIVILIZATION'S PROGRESS MEASURED IN GLASS.

To say that civilization's advancement is based on glass seems a gross exaggeration at first blush; and yet, when one reflects how many sciences and how much human knowledge came to the race through that commodity, the accuracy of the statement is apparent. The science of preventive medicine was born of the microscope. But for the telescope and the spectroscope the world would know about as much of astronomy as was known by the shepherds on the plains of Persia. One may read the whole list of technological industries without discovering lines of endeavor where glass does not play an essential rôle.

It was Pennsylvania that fostered the manufacture of this commodity in America, and it is from Pennsylvania today that the American people get a third of their supply.

The processes of manufacturing glass are extremely interesting. To see sand, soda, and lime mixed, subjected to heat, and turned into glass as transparent as the clearest water, or even as the very air itself, shows what liberties man has learned to take with Nature. Now as free-flowing as water, now as sticky as warm taffy, now as hard as flint, it lends itself to the manipulation of human hands and the purposes of man with astonishing versatility.

The mixed materials, technically known as the "batch," consist of white sand and such bases as potash, soda, lime, and lead. Small quantities of other materials are added as auxiliaries to change the color or nature of the glass. Manganese and arsenic are among the agents employed to make it colorless. For window glass a batch may be made up of 8,000 parts sand, 2,200 of soda sulphate, 2,500 of lime, 50 of arsenic, and 40 of powdered coal; or the amount of lime may be cut down and carbonate of soda substituted.

Window glass is of two kinds—cast and blown. The cast is the plate-glass of commerce. In making it the process is not dissimilar to the rolling of dough on a doughboard. A huge flat table with a rim around the edge is filled with a pile of hot putty-thick glass. A big mechanical rolling pin spreads it out after which it hardens. Then it is sent to the annealing furnace, heated, and allowed to cool gradually, for cooling either too fast or too slow would be ruinous. Finally it is ground down and polished and is ready for shipment.

FROM SOUP TO WINDOW GLASS.

The process of making blown window glass is entirely different. In hand-blowing, after the batch has been melted, the "gatherer" takes a pipe about five feet long, with a bell-shaped head at one end and a mouthpiece at the other, and dips the bell-shaped end into the molten glas. A small ball of the glass adheres. He blows through the pipe and transforms this ball into a thick-skinned bubble. When this cools sufficiently it is dipped into the molten glass again, and more adheres. The process is usually repeated five times, the bubble growing thicker of skin each successive time.

The pipe, with its adhering plastic bubble, is then given to a "snapper," or helper, who carries it to the

*Reproduced from *National Geographic Magazine* (Washington).

Courtesy of American Window Glass Co.

A machine-blown window-glass cylinder before the ends have been removed

"blower's block," where the "blower" takes it. The latter workman is the king bee of the glass industry—big of body, powerful of lung, and deft of hand. He places the bubble in the "block," which is an iron mold set in water to prevent its becoming too hot, and lined with charcoal to keep the iron from discoloring the glass. Compare photograph on page 88.

By turning the bubble in the block, blowing air into it as he does so, and gradually drawing the pipe upward, he slowly transforms it into a pearshaped affair. The lower part gradually becomes solid and too hard to be workable even with his powerful lungs. The snapper puts it into the blow furnace, and when it is properly heated he gives it back to the blower. Standing over the "swing hole," the blower allows the weight of the plastic glass to elongate the pear into a cylinder, which he gives the desired diameter by blowing into it intermittently.

But, although it has reached the desired diameter, the cylinder is not yet long enough to suit his purpose. So he reheats it and blows it over and over again until it attains the prescribed length.

At this stage the cylinder is completed, but the free end is closed and the other end still adheres to the blowpipe. It is put back into the blow furnace and the free end heated until it is soft enough to permit the blowing of a hole through it. The resulting imperfect end is cut away by wrapping a hot glass thread around the cylinder above the imperfection, at the point of severance. Touched with a piece of cold iron, the imperfect section breaks asunder. The cylinder is freed from the blowpipe in a similar manner.

We now have a perfect hollow cylinder of regulation window glass. But before it can be used in a window it must be flattened. To accomplish this it must first be split open. A hot iron or a charged electric wire, passed up and down the line of cleavage, plays the rôle of a pair of shears. It causes a strain-line to form from one end of the cylinder to the other, and when this is touched with a piece of cold iron the big roll breaks open as perfectly as though it were cut open with a diamond cutter and straight-edge.

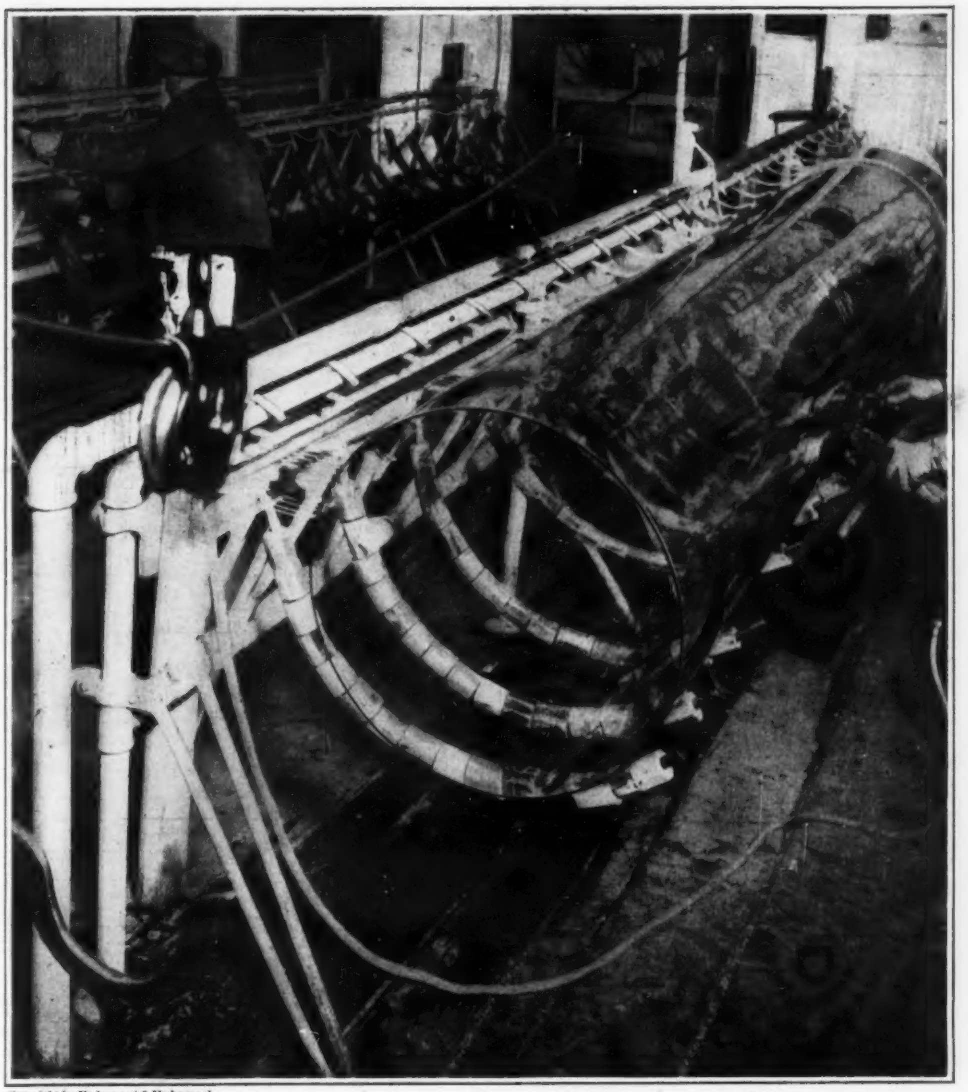
After this the roll of glass is sent to the annealing furnace. Heated to a proper degree, the glass becomes soft enough to permit the roll to be flattened. It is then carefully cooled and stored, ready for market.

MECHANICAL GENIUS A REVOLUTIONIZER.

By the hand-blowing process cylinders up to as much as six feet long and nineteen inches in diameter can be blown. Machine blowers have been gradually substituted and have revolutionized the art of making flat glass. All the larger cylinders, such as are illustrated on pages 81, 88 and 89 are machine blown.

In simple terms a machine blower is an apparatus which automatically dips a big pipe into a kettle of molten glass, and then gradually raises it, pulling all the molten glass upward as the pipe rises. A constant stream of air kept flowing in through the pipe causes the glass to assume the form of a cylinder. Dip a soda straw into a thimbleful of molasses, and blow through the straw as you lift it up from the molasses—that process would roughly duplicate the principle of the mechanical glass blower.

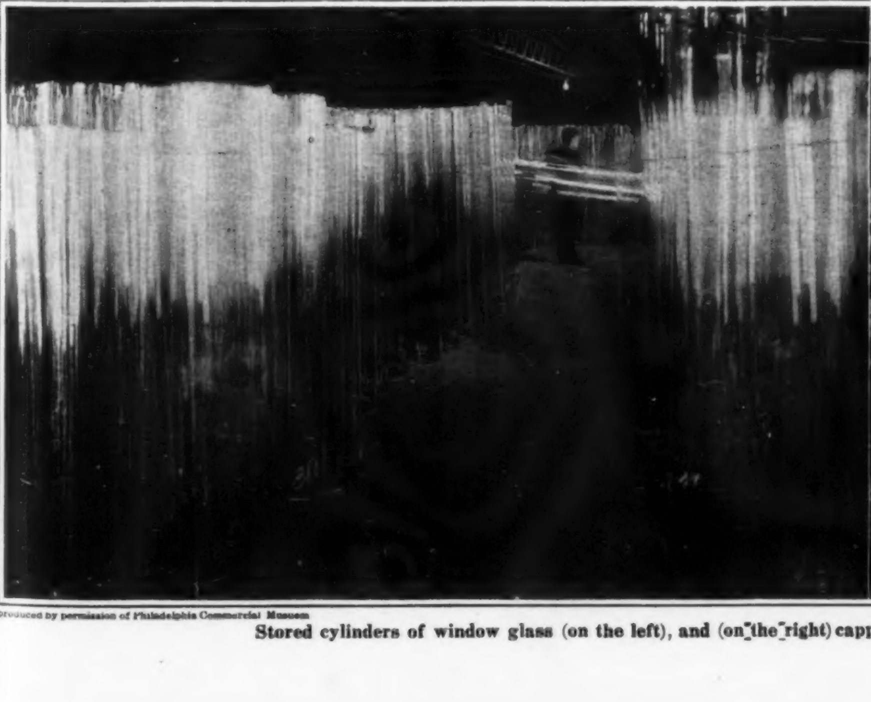
It would be too long a story to tell in this article the processes of making all kinds of glass; but it may be said that when the machine for blowing bottles came into use it changed the bottle industry as much as the mechanical blower changed the window-glass industry. Machines have been invented for blowing electric lamp bulbs also, but the hand blowers are still able to produce a major portion of these.



Cutting the glass cylinder with an electric hot point. After cutting and splitting the curved glass is flattened by whirling on a flat table in a hot furnace

Novel Leaf Prints

THE most exquisite leaf prints can be secured by an ingenious process. The first step is to soak a small square of white linen in spirits of nitre for about an hour. Select the leaf which it is wished to print and put this on a sheet of white paper, resting the whole thing on a flat surface. Then put the linen over the leaf and finally add another piece of paper. Press by means of a heavy book or anything of a similar nature. After two days it will be found that the leaf has lost all its color, but a most beautiful impression has been imprinted on the paper. Every vein stands up finely in green or whatever the actual tinting of the leaf may be. To protect the leaf print it is a good plan to give the paper a coating of clear varnish. By following this plan a most interesting collection of leaf prints can be secured which is of considerable value in the identification of the various kinds.



Stored cylinders of window glass (on the left), and (on the right) capping-off cylinders before flattening them

Physical Chemistry in the Industries*

Some of the General Principles Which Govern Its Application to Manufacturing Processes

By Dr. James C. Philip, M.A.

NEARLY up to the end of the past century chemical reactions were expressed in the form of equations, viz., $BaCl_2 + H_2SO_4 = BaSO_4 + 2HCl$. The equation was to be read from left to right and to indicate that in order to precipitate all the barium chloride in a solution, the equivalent amount of sulphuric acid should be added. This mode of expression was correct for the "complete" reactions of the analytical chemist who wished to remove one of the elements or components from his solution. It was quite understood, however, that the equation is only an approximation, that the last traces of a substance can hardly be determined in this way, since no substance is absolutely insoluble, while most reactions are reversible with conditions and proceed in one particular direction only until a state of balance is reached. Hence it became customary to replace the sign of equality $=$ by two arrows $\rightleftarrows$ and that change in notation was by no means unimportant. The old notation too much suggested finality, as if we could always direct a reaction in the desired sense, so as to obtain two new products. As a rule a mixture of the two original substances (reactants) and of the two decomposition products (resultants) will be obtained in proportions varying with concentration, temperature, pressure and other factors.

Investigated from the new standpoint of equilibrium reactions old-established technical processes have assumed very different aspects, an enormous amount of valuable quantitative data has accumulated, and physical chemistry shows also how new processes, considered possible but hopeless, can be rendered practicable under suitable conditions. The present generation of chemists is duly initiated into the principles of physical chemistry at the technical colleges. The older generation did not enjoy that advantage, which many other students have to miss likewise, and they will be grateful to Dr. James C. Philip, M.A., for devoting the three Cantor lectures delivered before the Royal Society of Arts to "Physical Chemistry and its Bearing on Chemical and Allied Industries." Dr. Philip is Professor of Physical Chemistry at the Imperial College of Science and Technology, South Kensington. We will attempt—although the task is difficult—to give an outline of these Cantor lectures, since the subject is of interest to engineers as well as to chemists and physicists.

Let us start from two reacting substances—gases, for simplicity sake—A and B yielding the products C and D according to the formula $A \text{ and } B \underset{v_2}{\overset{v_1}{\rightleftarrows}} C + D$

At any moment we have to deal with a mixture of the four substances. The symbols v indicate that the change from left to right proceeds at the rate v_1 and the reversed change at the rate v_2. Action between the molecules of A and B is only possible according to the kinetic theory, when A and B collide; the number of collisions, and hence the v_1 and v_2 depend, other conditions being constant, on the number of molecules present, *i. e.*, their concentrations, which we designate by a, b, c, d; hence $v_1 = k_1ab$, and $v_2 = k_2cd$, where k_1 and k_2 are constants. The observer can only determine the difference $v_1 - v_2$ not v_1 and v separately; as equilibrium is approached, this difference becomes smaller, until $v_1 = v_2$. Equilibrium does not mean stagnation and stoppage of the reaction, however; it signifies that there is as much change in the one direction as in the other, and that $k_1ab = k_2cd$, so that $k_1/k_2 = c\ d/a\ b = K$, the equilibrium constant. Here the $a\ b\ c\ d$ are the equilibrium concentrations. However the individual concentration values may vary, the law of mass action says that, at any given temperature, Y/X is a constant, where X indicates the product of the momentary concentrations on the left, and Y this product on the right side of equations.

Dr. Philip exemplified these relations in the first instance with respect to the contact process of sulphuric acid manufacture: $2SO_2 + O_2 \rightleftarrows 2SO_3$. The formula means that the combination of sulphur dioxide and oxygen to trioxide goes together with a dissociation of the trioxide. The process was the subject of a British patent as early as 1831; it requires the use of a catalyst, and troubles with the catalyst and imperfect knowledge of the principles of the reaction prevented technical success until the equilibrium was worked out in Germany a few decades ago. When we designate the equilibrium concentrations in the customary manner by the symbol C with the suffix of the substance, the quotient $C^2_{SO_2} \cdot C_{O_2}/C^2_{SO_3}$ should be a constant K at any temperature, irrespective of the initial concentrations. The C^2 in the formula indicates that two molecules of the substance enter into the reaction. The constancy of the K has been proved by experiments with various mixtures of SO_2 with oxygen and also with nitrogen at various rates of flow. At 727 deg. C., *e. g.*, $K \times 10^3$ was found to have the value 3.55, the presence of nitrogen not affecting this value. As the temperature was raised from 528 deg. to 897 deg., the K increased from 0.015 to 81.6×10^3. This K, however, refers to the reverse reaction, the decomposition of SO_3, and we see that the higher the temperature, the more trioxide will be dissociated, and that we should therefore work at relatively low temperatures. The combination of SO_2 and O is, in fact, an exothermic reaction, evolving heat, and the quantity Q of heat evolved is given by: $d \log K/d\,T = -Q/R\,T^2$, T being the absolute temperature and R the gas constant; the value Q is $-47{,}300 + 4T$. To arrive at the optimum gas proportions we write the equilibrium formulæ $C^2_{SO_3}/C^2_{SO_2} = C_{O_2}/K$ or $C_{SO_3}/C_{SO_2} = \sqrt{C_{O_2}}/\sqrt{K}$, which shows that the ratio of trioxide to dioxide in the mixture is proportional to the square root of the oxygen concentration and will rise, as the latter is increased.

The falling-off in the yield of trioxide at high temperatures can also be derived from Le Chatelier's principle: When any change in the external conditions (pressure and temperature) is imposed upon any equilibrium system, then the equilibrium shifts in such a direction as partially to neutralize the change in question. This principle—really inherent in the laws of thermodynamics and in the general principle of action and reaction—says, *e. g.*, that, since heat is evolved by the formation of the trioxide, the reverse process, the dissociation of the trioxide, must absorb heat, and rise of temperature hence favors the dissociation. Similarly increase of pressure favors the formation of the system occupying a smaller volume, and would hence promote the formation of the SO_3, there being two molecules on that side of the equation against three on the other; so far, however, there is little inducement to work the contact process at high pressures. Dr. Philip did not indicate how quantitative relations can be determined by the principle of Le Chatelier and Braun, which does not seem to lend itself to calculations.

For the manufacturer it is essential that equilibrium should be reached in a reasonably short time. The velocity of most chemical reactions now is doubled and even trebled by the small temperature rise of 10 deg. C.; but high temperatures, the lecturers informed us, lower the yield. A compromise has hence to be effected as to temperature, depending upon the choice of the catalyst. With the very efficient catalyst, platinum, the contact process can be worked at 400 deg. or 500 deg. C.; ferric oxide Fe_2O_3 (from roasted pyrites) has to be heated to 600 deg. to become efficient. Dr. Philip mentioned that at Mannheim a first rough catalysis with Fe_2O_3 is followed, after absorption of the SO_3 formed, by a second catalysis with platinum.

Dr. Philip took his second illustration from the synthesis of ammonia: $N_2 + 3H_2 \rightleftarrows 2NH_3$, a reaction long known, but only worked out by Haber about 1905. The formation of ammonia requires high pressure. Designating the partial pressures by p, the total pressure of the mixture by P, he showed that $p^2_{NH_3}/p_{N_2} \cdot p^3_{H_2} = K$ at any given temperature, and that, since p_{NH_3} is small at high temperatures by comparison with the other partial pressures, $p_{NH_3} = 0.325\ K \times P^2$, that is to say, the partial pressure of the ammonia in the equilibrium mixture is, for low ammonia concentrations, proportional to the square of the total pressure, while the volume percentage of ammonia at equilibrium is equal to $0.325\ K \times P$, and thus proportional to the total pressure. Haber demonstrated, *e. g.*, that the volume percentage of ammonia in the equilibrium mixture was 0.12 at 800 deg. C. and 1 atm. and 3.4 (30 times as great) at 30 atm. and the same temperature. This synthesis being again exothermal, very high temperatures are not desirable; at 30 atm. the value of $K \times 10^4$ went down (Haber) from 21.3 at 561 deg. C. to 1.18 at 952 deg. C., experiment and calculation being in closest agreement, while at 200 atm. the equilibrium percentage of ammonia was raised to 85.8. Pressures of 150 atm. and 180 atm. and temperatures between 500 deg. and 600 deg. are hardly exceeded in practice. The actual time of contact between catalyst and gas is only a few seconds or a fraction of a second. Dr. Philip mentioned that by extrapolation from the formula, Maxted has recently shown that the ammonia yield should decrease when the temperature was raised to 2,500 deg. at 1 atm., and should increase on further raising the temperature. He stated that he had supported this deduction by experiments; technically very high temperatures have not been tried yet.

In his second lecture Dr. Philip pased to further consideration of the reaction velocity, $V = v_1 - v_2 = k_1\,a\,b - k_2\,c\,d$. Let a_0 and b_0 be the initial concentrations of A and B, and x the concentrations of both C and D after the interval t; then $V = k_1\,(a_0 - x)\,(b_0 - x) - k_2\,x^2$. When the velocity of the reverse reaction is negligible, $k_2 = 0$, and when in a particular case the change of x with t can experimentally be observed, the velocity k_1 or K can quantitatively be determined. This can be done, *e. g.*, in experiments on the saponification of ethyl acetate with caustic soda, and the velocity coefficient is found to be constant. Going back to the general case, a reaction $A + B \rightleftarrows C + D$ is called bimolecular; a reaction of the type $A \rightleftarrows B$ (conversion into a modification) or $A \rightleftarrows B + C$ (dissociation of a molecule or compound) is unimolecular; a reaction involving more than 2 moleculars is one of higher order. When all the reactants are either gaseous or liquid, the change is called homogeneous; when solids enter, the change is heterogeneous.

In homogeneous reactions the catalyst—a substance which accelerates the reaction—retains its efficiency unimpaired for long periods, provided it can be kept pure. Working with pure gases the Badische Anilin- und Soda-Fabrik used the same platinised asbestos continuously for ten years, realizing a 95 per cent. yield of SO_3. But when they utilized the SO_2 from roasted blende and pyrites, the yield diminished much in spite of all purification by cooling, scrubbing and filtering, mainly owing to the arsenic fumes apparently. To facilitate the recovery of the platinum, the catalyst is, in the Schröder-Grillo process, prepared by soaking a solution of magnesium sulphate with platinum salt and then heating the mixture; the platinum of this catalyst makes up 0.1 per cent. of the mass, and 5 grammes of platinum suffice for an output of 1 ton of oleum per day with a loss of 20 milligrammes of platinum. The exceedingly small percentage of the catalyst supports the view that the final equilibrium is not dependent upon the presence of the catalyst which acts like a noil facilitating the sliding down of a weight on an inclined plane, without affecting the total energy rendered available by the falling mass.

In the case of the conversion of acetaldehyde into paraldehyde the various catalysts (several acids, SO_2, zinc sulphate, &c.), at different concentrations all give the same K, and as K is the ratio k_2/k_1, it follows that both the reversible reactions must be accelerated to the same extent. The rate of inversion of cane sugar by acids, on the other hand, varies greatly with the acid, the relative rates obtained with hydrochloric, sulphuric and acetic acids being 100 : 54 : 0.4. Most technical catalyses, moreover, are of the heterogeneous type, and there the relations are not so simple, other factors coming into operation besides mass action. Dr. Philip referred in this connection to the hot-surface combustion (Bone-Court), and to the studies of Bone and Wheeler on the reaction $2H_2 + O_2 \rightleftarrows 2H_2O$, the combustion of electrolytic gas. This combustion looks like a trimolecular reaction; in the many series of experiments made with different gas mixtures and unglazed porcelain as catalyst the values of K did not at all prove constant on that assumption, however, but did prove constant when the reaction was considered to be unimolecular. That fact, Bone suggested, shows that the rate of change essentially depends upon the occlusion of hydrogen by the porcelain; what is measured is hence not the chemical combination of hydrogen and oxygen, which is probably instantaneous, but the physical process of hydrogen occlusion.

Another class of technically important catalyses, the hydrolysis of carbohydrates by enzymes (living organisms of complex nature) deviates from the law of mass action in so far as the velocity of the reaction, instead of being constant throughout, first increases for 40 minutes, in the case of starch and malt extract, *e. g.*, and then remains practically constant; with maltose, however, this initial period is very short. In another

*As reported in *Engineering*.

field, that of the hardening of oils and fats by hydrogenation—a problem to which we have referred on previous occasions—the previous history of the catalyst plays an important, not yet understood part. The catalyst generally used for the purpose of making the oil combine with more hydrogen is metallic nickel, reduced from the oxide or the hydroxide, themselves obtained from various salts; the method of reduction is of great influence. In order to secure a very fine subdivision of the catalyst, nickel carbonyl, which decomposes at 200 deg. C., has been directly mixed with the oil. Still more efficient is the Lesing process which supplies the nickel carbonyl along with the current of hydrogen passing into the oil at 200 deg. C.; the nickel then acts as soon as liberated, and excellent results have been obtained with 0.1 per cent. of nickel, while of ordinary nickel catalysts 5 per cent. may be wanted. For these nickel catalyses carbon monoxide seems to be a "poison."

Dr. Philip also dwelt on the oxidation of ammonia by air in the presence of bright platinum at dull red heat. The reaction is $4NH_3 + 5O_2 \rightleftarrows 4NO + 6H_2O$. We referred to this process recently in our issue of November 1 (page 498). As regards the mechanism of catalysis, it has been suggested, Dr. Philip stated, that the catalyst forms intermediate compounds, *e. g.*, with the oxygen which are decomposed again by the hydrogen. The chemical view, Dr. Philip pointed out, was only tenable if this rate of the formation and decomposition of the intermediate compound were greater than that of the uncatalysed reaction, and in many cases, for instance, with catalysis by glowing porcelain, such compounds seemed to be out of the question. Yet the physical condition of the surfaces might be altered by these intermediate reactions, and surface condensation and concentration were certainly to be reckoned with. No single theory would fit all cases of catalysis, however, and chemical and physical factors had to be taken into account.

In the domain of absorption phenomena we find again that the problems can be exactly formulated for gases and liquids, but become more complicated when solids are concerned. According to Henry's law the volume V of a gas taken up by unit volume of a liquid is proportional to the pressure P under which the absorption takes place. Thus for carbon dioxide and water, when P is expressed in centimeters of mercury and V in cubic centimeters at normal temperature and pressure, V/P has the fairly constant value 0.145. That holds also for the absorption of acetylene by acetone which takes up 250 volumes of acetylene; the acetone expands when absorbing the acetylene, and for this and other reasons the steel cylinders are partly charged with some porous absorbent, as we noted in our article, published early this year, on "Cylinders for Dissolved Acetylene."[1]

Since the absorption increases with pressure, and water absorbs at ordinary temperature nearly 50 times more carbon dioxide CO_2 than hydrogen, the bulk of CO_2 can be removed and separated from the hydrogen in water gas by exposing the gas to water under pressure. Water dissolves at 0 deg. C., 0.0489 volume of oxygen, 0.0239 of nitrogen, 0.0215 of hydrogen and 1.713 of carbon dioxides, and at 20 deg. C. 0.031, 0.0164, 0.0182, 0.0878 volumes. More oxygen is thus taken up from air than nitrogen, and more oxygen given up again subsequently on releasing the pressure. Now air contains 21 per cent. of oxygen; by one absorption this percentage is raised to 33, and by eight successive absorptions to 97; such processes for the commercial production of oxygen have been patented, but they are hardly commercial. The purification of the crude ammoniacal liquor from sulphuretted hydrogen H_2S and from CO_2 is, however, carried out on this principle by a process patented by Hills in 1868. The liquor is passed in a tower over a series of trays steam-heated from the bottom; the CO_2 and H_2S being less soluble in the liquor than the ammonia, small percentages of the former two gases can be reduced to about one-tenth of their values, 0.12 and 0.04 per cent. Dr. Philip also referred to the caisson-sickness, which is mainly due to the liberation of nitrogen from the blood on decompression; the oxygen remains bound in the blood, in labile fixation.

Since the concentration of a gas is proportional to its pressure, we may write Henry's law also $C_l / C_g = K$, designating by the C the concentration in the liquid and the gaseous phase. When a solid is present, the amount of gas taken up by the solid Cs is also found to increase regularly, but at a slower rate than the pressure; the simple relation $C_s/C_g = K$ does not hold, therefore, but in many cases the formula $C_s / C_g \frac{1}{n} = k$ is applicable, *e. g.*, for charcoal and carbon dioxide where $n = 3$. It is believed that the gas absorbed by a solid is not uniformly distributed throughout the solid as it is in a liquid. There is a "dual" relation, in fact. There is first a very rapid adsorption of gas or liquid by the surface layer of the charcoal, followed by a much slower diffusion and penetration of the gas into the interior of the charcoal (absorption). The former surface effect is a question of seconds or minutes, the latter of hours and days. The regularity of the phenomena may therefore be obscured; but many experiments made at rising and falling pressures and temperatures have established the applicability of rules. The whole series of the phenomena of surface films of gases and occlusion of gases[2] fall into this category. It is well known that charcoal becomes a very powerful absorbent for most gases at very low temperatures. It is not understood, however, why different kinds of charcoal from various woods, differently treated, differ so strongly as to absorptive power. The masks developed during the war for the absorption of poison gases contain charcoal. Treated successfully with "doses" of 6 liters of air charged with 1 per cent. of poison gas, Dr. Philip mentioned three charcoals, A, B, C retained successively: A, 78, 5, 0; B, 100, 20, 0; C, 100, 100, 97 per cent. of the gas; all the three charcoals were the same, but B had been heated four hours, and C six hours longer than A.

The dual character of the sorption by solids is also distinct in cases when charcoal and other absorbents are first charged with a substance (iodine, acetic acid) by being left in contact with a solution of the substance and then shaken or left in contact with a more diluted solution of the same substance. Silk, *e. g.*, takes up picric acid from solutions, and gives it up again when shaken with the solvent afterwards, the equilibrium being reversible. If the whole dyeing process relied on this sorption only, fast colors would be impossible, but chemical reactions and other factors come into play in dyeing. Vegetable and animal charcoals, Fuller's earth, clays, colloids, are largely utilized as absorbents. We do not know why certain modifications of their preparation, frequently merely shorter or longer heating, or the presence of ashes apparently, so strongly affect their efficiency, and we cannot help that the animal charcoal, which is to remove the coloring matter and other impurities from the sugar solution, also absorbs sugar. But part of this sugar can be recovered again by washing the charcoal with water, because the process is an equilibrium reaction. All these considerations are of signal importance also in soil problems. If the soil were not able to retain the salts used for fertilization, the rain would wash out the fertilizer. Colloidal gels in the soil seem, however, to be capable of absorbing the base (ammonia, *e. g.*,) leaving the sulphuric acid to combine with the lime, somewhat as the fibre combines with the basic dye, and sewage farming is based on an adsorption of organic matter by the soil. But these problems are still obscure.

[1]See *Engineering*, February 8, 1918, page 155.

[2]See *Engineering*, 1918, page 562 and 583 *ante*.

Eperimental Wireless Telegraphy and Telephony

(*Continued from page 85*)

SIMPLE RECEPTION OF UNDAMPED WAVES.

While damped waves are transmitted as detached groups or trains, undamped waves are usually not separated into groups. Undamped waves, even if rectified, will not be detected in a telephone receiver unless the waves are broken up into groups in some way. This is because the telephone diaphragm and the ear cannot respond to so high a frequency as that of the radio oscillations. Hence it is necessary to interrupt the undamped wave dot or dash into many groups by rapid interruptions of the current. It is arranged in practice to have, for example, 1,000 interruptions a second, giving a 500-cycle note in the telephones; and as long as a signal continues a note of pitch 1,000 is heard. These interruptions may be made to take place either at the transmitting or the receiving station. A method for producing them at the transmitting station is to insert a rapidly operating circuit breaker called a "chopper" in the antenna wire; or if it is inconvenient to break the current, the chopper may be used to short circuit some of the turns of the antenna inductance coil to throw the circuits out of resonance periodically. This divides up the waves into groups to which the receiving telephone can respond. A rather more convenient method is to have the chopping done at the receiving station, for then the receiving operator can control the pitch of the received signals at will thereby listening to the note best adapted to his ear. There are at least five ways of modifying the waves at a receiving station to obtain an audible frequency: (1) a chopper in series with the detector and telephone; (2) a variable condenser with rapidly rotating plates; (3) a "tikker" used instead of a detector; (4) a "heterodyne" in a separate circuit; (5) an "autodyne" or vacuum tube device arranged so that the detecting tube also produces the heterodyne action. The last method is explained in the section dealing with vacuum tubes, further on.

The chopper may be any device for rapidly making and breaking the current. It is inserted in the circuit of the detector and telephone as in the ordinary damped wave set. It consists of a rotating toothed wheel with stationary contact touching the successive teeth, or a break controlled by an electrically-operated tuning fork, or it is sometimes a light high speed vibrator similar to that of an electric bell.

If the movable plates of the tuning condenser in an inductively coupled set are rotated rapidly the apparatus will be in tune once for each revolution. Each of these revolutions will produce an impulse of the telephone diaphragm. The speed can be adjusted so that the impulse will cause sounds while waves are being received. In practice it is found best to keep part of the capacitance of the condenser constant, and vary only a part of it. If the main plates were rotated the apparatus would give sounds at only a small sector of each revolution, near the resonance adjustment. To accomplish a more prolonged train of impulses during one revolution the adjustment can be held near resonance for a longer proportion of the time if the rotating condenser is made very small, and is placed in parallel with the condenser. The large condenser does not then rotate except for ordinary hand tuning. The capacitance of the large condenser plus the maximum capacitance of the rotating condenser is adjusted to give resonance. The circuit is not far from this condition when the moving plates are farthest apart, so that the signals affect the receiver during a considerable portion of the revolution.

The tikker is usually a stationary fine wire of steel or gold with its end running in the groove of a smooth, rotating brass wheel. It is a slipping contact device. The wires do not remain in perfect contact with the wheel, but owing to the slight irregularities there are variations of contact, which in effect keep making and breaking the circuit. Referring to the thirteenth sketch, with the tikker contact open, suppose the secondary inductance and condenser C_2 to be tuned to resonance with the incoming waves. If now the tikker is closed when C_2 has any stated value of charge, some of the charge will be given to the condenser C and furthermore the radio oscillations cease because the addition of C throws the apparatus out of tune. When the tikker is opened the condenser C discharges through the telephone, and in the meantime the secondary oscillations build up again, ready to give a charge over to C when the contact is closed. In this manner the current impulses through the telephone are of the same frequency as the operation of the tikker, and this can be controlled by the speed of the wheel. The capacity of C should be about 1 mfd. No separate rectifier is needed. The tone obtained is not musical, since C_2 is charged to different potential differences at the different times when the tikker closes, and the action depends also upon a somewhat irregular contact.

In the heterodyne method an apparatus is arranged to produce undamped electric oscillations in the receiving circuit, of nearly the same frequency as that of the waves which are being received, and their combined action is made to affect the receiving telephone. Beats are produced having a frequency equal to the difference of the frequencies of the two waves. The connections are shown in the fourteenth sketch. Any source of undamped or slightly damped oscillations is connected at A. In the antenna circuit at B is a single turn or loop, coupled inductively to A. The antenna circuit thus gets the effect of the oscillations from A as well as from the incoming waves. Suppose those received have a frequency of 100,000, and the heterodyne A is adjusted to give a frequency of 99,000. As long as both act, the telephone will respond to a pitch of 1,000 vibrations per second, which is of course audible. When the incoming waves cease, the heterodyne continues to act along at 99,000, but this is inaudible. Therefore signals are heard only during the time when the incoming radio waves are received.

While a radio telephone transmitting apparatus operates on undamped waves it is not necessary, or indeed permissible, to use a chopper, tikker, or heterodyne at the receiving station. The transmitted waves are modified or varied in intensity by the spoken sounds and these sounds are reproduced in the telephone of the ordinary receiving set such as is used for damped waves.

(*To be continued.*)

The Lilies of the Field

Beautiful and Striking Wild Lilies of California's Fields

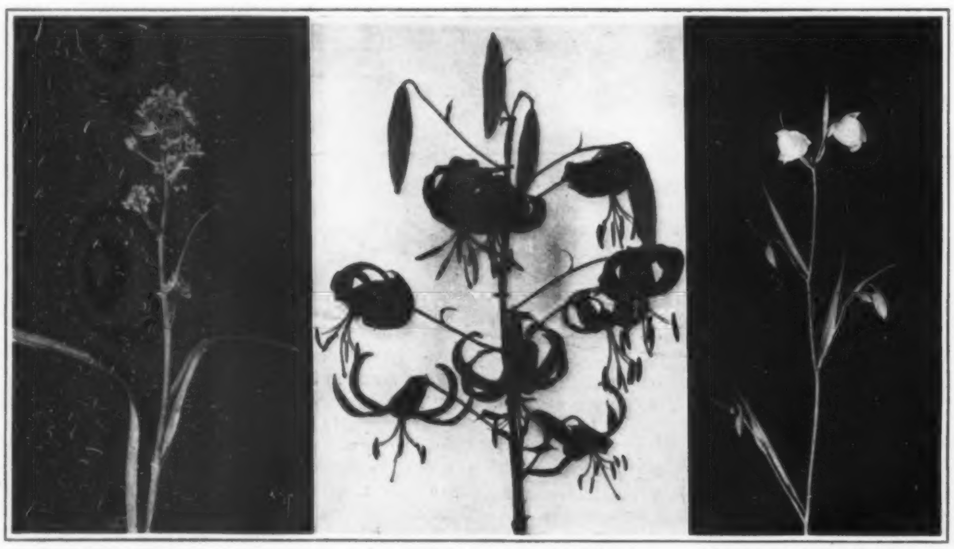
By Francis M. Fultz

Amole or evening-blooming soap plant (hlorogalum pomeridianum) and its fiber-bound bulb

CALIFORNIA is wonderfully rich in wild flowers of the Lily family. Very nearly as many species of this group are to be found within its borders as throughout the whole expanse of our country east of the Rocky Mountains. And the number of beautiful and striking ones is far greater than in the East.

Another noteworthy thing about them is the character of their habitat. In the East we expect to go to the swamps and wet places for the lilies. A number there grow in the moist woodlands, but scarcely any at all on the dry uplands. It is different in California, especially in the southern part. There we find very few of the lilies growing in swamps. We have to go to the dry foothills for most of them. Indeed, we find some of the most beautiful growing in ground so hard that should we want the bulb, we must dig it out with a pick. It is marvelous how flowers of such wonderful structure and exquisite beauty can mature under such conditions. For a while it upsets our deep-rooted ideas concerning the growing habits of lilies. But by and by we get used to it; and like it, too, for it means we may find some of the Lily sisterhood almost anywhere we go, and that among them they make their season extend from February to September.

The Brodiæa leads the procession of California lilies. Of course there are several California Brodiæas, some four or five at least. But this early one that I speak of is *Brodiæa capitata*, one of the most plentiful and universal of California flowers. It is variously known as "Wild Hyacinth," "Cluster Lily," "Blue Dicks," and "Grass-Nuts." This last name it gets from the children, who love to dig and eat its toothsome bulbs. Occasionally it is called "Spanish Lily," and some people —who are "born short" esthetically—refer to it as "Hog Onion." The practice of calling it simply "Brodiæa," or "Blue Brodiæa," is spreading, which is gratifying, as it is certainly *the* Brodiæa of California. Beside being found in almost every quarter of the State, it is equally at home in every sort of location, at any altitude up to a mile or more above sea level.



Zygodene, a trail lover — Leopard Lily (L. pardinalum) a cañon flower — Lantern of the Fairies, on moist north slopes

Of the other California Brodiæas, only one is found in the South. This is the Harvest Brodiæa (*B. grandiflora*) and it does not here attain the size and luxuriance that it does in the North. It is of a clearer blue than the *capitata*—it might be classed as a light-violet —and its individual flowers are three or four times the size of those of its earlier-blooming sister. In the North, where it attains its highest perfection, there are likely to be several flowers of each cluster in bloom at once, making a fine display; but in the South it is very seldom we see more than two full-blown flowers in the same cluster; usually the blooms come singly, each fading as the next one is ready to open.

Along with the early Brodiæas comes the Black or Chocolate Lily (*Fritillaria biflora*). This flower is so remarkable in color as to attract the attention of even the most unobserving stroller on the hills. I have seen it a black-brown on the open foothills near the coast, and a black-green high up on the mountain inland. In the former case, the 8- or 10-inch stalks carried from one to three bells each, two being the almost universal number; but in the high inland valleys I have found the scapes loading themselves down with the greenish black blooms, until they literally sagged beneath the floral burden. Ten to fifteen bells to a stalk was common, and I came across one which bore an even twenty. In a high mountain valley in the northern part of Ventura County I once ran onto a glorious array of these black-green fritillarias. They had pre-empted an old abandoned field, and were making beautiful the land which men had long discarded as not worth his care and attention. Among the dome-topped towers were some that held near a score of bells, and few there were from which did not swing at least ten or a dozen. It is evident that the botanist who named the species *biflora* had never seen such a display of these fritillarias as this.

After one has heard the legend of the Fritillary, telling how she came by her somber hue, he must needs recall the story whenever he sees the hanging bells. The legend runs as follows:

In the long ago the Fritillary was white, and, vain of her beauty, held her flowers proudly aloft with their cups open to the blue sky above. At the time of the crucifixion of the Christ all the flowers hung their heads in grief and sorrow; all but the proud Fritillary, who stood unmoved, still holding aloft her cold, white flowers; but at the death of our Lord, when the earth trembled and was swathed in darkness, the Fritillary was struck with remorse. She hung her head in shame, clothed herself in mourning hues, and shed tears of bitter grief. And to this day she has not ceased repenting her haughty pride.

Although I always think of the legend when I see the Fritillaria, I do not so interpret her attitude. To me it tells a story of retiring modesty and artless grace.

Calochortus catalinæ leads the van of that splendid troupe of California lilies which we call Mariposas, of which there are a dozen or more, and which follow along after one another in an illumined procession from early March until Summer is well spent. Most people call them lilies, and they are such, of course, yet it would be more distinctive to call them "tulips," to which division of the Lily family they belong; as may be easily seen from their structure, the three innner divisions of the perianth being large and showy, while the three outer ones are small and bract-like.

There are three divisions of the genus *Calochortus*: Mariposas, or Butterfly-Tulips; Globe-Tulips, and Star-Tulips. *Mariposa* is Spanish for *butterfly*, and the name has been very aptly applied to this group of *Calochortus*. There are about twenty species of *Calochortus* in California, somewhat more than half of which are Mariposas. The South is particularly rich in the number of species.

The Mariposas form a remarkable and charming group. None of them, perhaps, has the air of refined purity possessed by the Satin-Bell, or Lantern of the Fairies as it is often called—one of the Globe-Tulips—but for tints and blends of color they give us masterpieces that no other flowers attempt to copy; and some of them have a slender grace which no other of their wildwood companions seem able to attain.

The Catalina Mariposa, this earliest one of the butterfly flowers, is by no means so gorgeous as some of her later-blooming sisters, yet we give her a right royal welcome each spring when she makes her appearance, and for a while she claims a large share of our wild-flower homage. She rules over a territory along the South Coast, and on the nearby islands of the sea—from one of which she gets her name. None of her sister Mariposas invades her domain to any considerable extent. She dresses herself in a gown of white, which she tints with a breath of lilac. Sometimes it is as if she got in more of the lilac than she should, and her gown becomes a lavender. But she never makes any mistakes about the deep garnet patches on the inside of the three large petals, and on the outside of the three small ones in the same position. They are constant birthmarks.

Closely following the Catalina beauty, comes her rose-lilac sister, *Calochortus splendens*. She is uniform and constant in color, is somewhat taller, and more slender of stalk than the *Catalinæ*, and makes her home further inland. She is also more tolerant of shade. She is at her best in May; but she lingers along until late in June, when the Godetias—for which she is sometimes mistaken—are brightening the trails.

About the same time—perhaps they are a week or so later in arriving—four other Mariposas are adorn-

C. catalinae C. kennedyi C. occulatus

Catalina, Red and "eyed" Mariposa Tulip

ing the slopes of the Southern mountains. They are *C. occulatus*, *C. citrinus*, *C. venustus*, and *C. clavatus*. It is unfortunate that none of these has a generally-used common name. The best we have to offer is "Butterfly Tulip" for the *occulatus*, "Yellow Butterfly Tulip" for the *citrinus*, and "Golden Butterfly Tulip" for the *clavatus*. The poor *venustus*—which in coloration is the most striking one of all—has no name by which she is known to the common herd, except "Mariposa Tulip."

The *occulatus* and *citrinus* have been generally given as varieties of the genus *Luteus* by botanists, but the present tendency is to make them distinct species.

Blue Brodiæa (B. capitata)

They may be classed as extreme ends of a widely-varying type. Their forms run into each other until the result becomes bewildering, even to one who is familiar with them. They also hybridize with *venustus*, and perhaps with *catalinæ* and *splendens*, until even the expert botanist is sometimes in despair.

The most evident distinction between the *citrinus* and *occulatus* is that the former is a lemon-yellow, while the latter may be of almost any color but yellow; and that the *occulatus* has a beautiful peacock "eye" near the center of each petal—whence comes the name of "occulatus"—while in the *citrinus* it is almost wholly, or altogether, wanting. Besides having the central eye of varied and iridescent hues, each petal of the *occulatus* is deeply marked at the base and top in a manner that is only a shade less striking. Indeed, the blotch at the tip is often a real secondary "eye." And not infrequently the three are combined in a medallion-like figure extending the whole length of the petal. When hybridizing with the *venustus*, the *occulatus* acknowledges no law for color or markings.

Once in the San Rafael Mountains I ran across a ridge that was a perfect revel of color from the mingled and hybridized blooms of the *occulatus* and *venustus*. The display surpassed anything I have ever seen in Mariposas. There were white and lilac and pink; there were lavender and purple and rose; there were magenta and claret and brown; almost any color you could name; even light-yellowish. Deep-yellow alone was wanting—in the combinations of *venustus* and *occulatus*—and that was furnished by the *clavatus*, that sturdy, upstanding *Calochortus*, the giant among the Mariposas, which here and there rose among the multitude of the more lowly and slender *venustus* and *occulatus*, towering above them, and lifting its great golden cups straight upward to the sky. This Golden-Butterfly Tulip is one of the queens of the wild-flower host in June.

The Mohave Desert furnishes us a distinctive Mariposa in the *Calochortus Kennedyi*. Here it is blood-red, but in Arizona, where it is more plentiful, it takes on something of an orange hue. The flower is from one to two inches across, and about the same in depth,

Blue Brodiæa (showing slender scapes and grass-like leaves

and so perfectly cup-shaped that novices take it for a poppy. Its stems are apt to be decumbent, often running under the sand for some length, and then shooting upward but a few inches to bear their flaming chalices.

The "Sego Lily" (*Calochortus Nuttalli*), the State flower of Utah, is said to be found in the mountains east of San Bernardino, but I have never seen it.

The latest of the Mariposas to adorn the mountain slopes in southern California is the *Calochortus Weedii*. This one, too, has no common name; which is a pity, as it is widely distributed and a general favorite. I call it the Brown Mariposa, because of its general color effect. But this name is unsatisfactory. It is deserving of some pleasing and distinctive name. It is not a striking flower as you see it blooming on the dry foothills, but when you pick it, and look into its perfect, goblet-shaped cup, you are fascinated with its exquisite structure and markings. This Mariposa is always a wonder to me. How its small bulb, which in the springtime throws up but a single leaf—that lasts only a few weeks, then withers and dies—can store up enough substance to produce in midsummer the tall stalk and marvelous flowers is to me a miracle! For at blooming time the ground in which the bulb lies is as dry as a bone, and almost as hard; while the unclouded sun sucks from the atmosphere whatever of moisture the winds may bring in from the sea.

Of the Globe-Tulips, the South has the Satin Bell (*Calochortus albus*), or "Lantern of the Fairies," as it is often called. It is well known and a favorite wherever it grows, and is found quite generally throughout the State south of the Bay Region. It has a wealth of common names. Besides those already given, it is known as "Snowy Lily-Bell," "Hairbell," and "White Globe-Tulip." To one who is familiar with the Mariposas only, as the type for *Calochortus*, the Satin-Bell would scarcely at first be suspected of belonging to that genus. Instead of opening to form a lovely cup, as in the Mariposas, the petals form a globe which hangs

Golden Stars (Bloomeria aurea)

pendent, and which swings with the slightest breeze. These globes are white, and of a pearly, satiny luster that bewitches even those who are not special enthusiasts over wild flowers. If anything were needed to complete the conquest, the delicate fringing of the petals would do it. No other wild flower, unless it be one of the Star-Tulips, matches the exquisite air of the Lantern of the Fairies.

The "Leopard-Lily" (*Lilium pardinalum*) is one of the few which seek the moist places for their home; so to find it you must go to the deep canons, or to the

Golden Butterfly Splendid Weed's

Mariposa "Tulips" (Calochortus)

Deep Chocolate Black-green

Chocolate Lily (Fritillaria biflora)

Harvest Brodiæa (Brodiæa grandiflora)

slopes which are fed from the melting snows and high-up springs. In such places it is to be found quite generally throughout the South. In the nearer canons of the Coast Ranges, however, it has been sought and gathered so diligently that one must now go far up into the mountains to find it. On the San Rafael and other back coast ranges it is still plentiful—and always glorious.

The Leopard-Lily is one of the few California wild flowers which make an Easterner think of the garden that surrounds his childhood home, where the tiger-lilies held a prominent and an honored place. These

Spanish-Bayonet (Yucca whipplei) about 15 feet tall

California Leopard-Lilies are not the same, however, although the casual observer usually thinks so. The tiger-lily of our gardens is an importation from Asia.

The Leopard-Lily is a strong grower and a prolific bloomer. The stalk is seldom less than five feet in height, and I have seen it so tall that I could not begin to reach the topmost blooms. And then its floral wealth! A score of the three- or four-inch, orange-colored, deep-dotted flowers on a single stalk is no unusual sight, and even double that number not at all uncommon.

Throughout the Sierra Nevada Range there is a closely related lily (*Lilium parvum*) which is locally called "Tiger-Lily," or "Little Tiger-Lily." The latter name is used, I presume, to distinguish it from the Leopard-Lily, which is frequently called the "Large Tiger-Lily." This Tiger-Lily of the Sierra is much smaller, both in stalk and flower, than the true Leopard-Lily. The flowers are somewhat lighter-colored, too, shading from yellow at the base through orange at the middle to almost red at the tips. The dots are more red than deep-orange, as in the Leopard-Lily. What the Little Tiger-Lilies lack in size and number to the stalk—there are usually not more than five or six—they make up by the profusion with which they occur. In the southern part of the Sierra Nevada I have seen stretches along northern slopes, acres and acres in extent, where these industrious Tiger-Lilies were preempting the earth to the exclusion of almost all other herbaceous growth.

Photo by courtesy of Macbeth-Evans Co.

Glass-blowing at a Pennsylvania plant (see page 89)

A growing Leopard-Lily stalk always attracts and holds my attention. And I have noticed that it generally does the same with all those who happen to be my companions on the mountain trails. June and July are the best months in which to observe it. Story after story it mounts upward, each step marked off with a whorl of dark-green, lanceolate leaves some three or more inches long, which at first stand straight out, but later droop and crinkle. Week after week the stout stalk climbs, until it is far above one's head, and one begins to wonder if it *ever* intends to bloom. But it is just getting a good ready. And the display it makes in August fully justifies the time it takes in getting ready.

In the San Bernardino Mountains, and on into Arizona, the "Lemon-Lily" (*Lilium parryi*) reigns as the undisputed queen of her tribe, if not of the whole floral sisterhood of that region. Her dress is a clear lemon-yellow, over which are sprinkled dots of deeper yellow. In size of flower and in habits of growth this charming lily resembles her darker sister, the Leopard-Lily, although the latter is somewhat more sturdy of stalk. The petals of the Lemon-Lily, too, are not so strongly curved as are those of the Leopard-Lily. The former also accommodates itself to a dryer soil and more open country.

In the late spring we run across bunches of long, crinkly leaves, as we traverse the foothills and lower mountain slopes. From their appearance, we rather guess they belong to some lily, so we watch them with interest to see what manner of flower they will bring forth. Along about May, a stalk shoots up out of the center of each bunch, and the leaves begin to wither. The stalk shoots up at the rate of two or three inches a day, and by the time it is a couple of feet high, it is covered with buds. It sends forth numerous branches, which are also covered with buds. Except for these flower-buds, both stalk and branches are bare. The only leaves which the plant has are those at the base. The stalk continues to mount upward until it reaches a height of six or eight feet. But it does not wait until it attains its growth before it commences to bloom. By the time it is three or four feet high the lower flower-buds begin to open. Then we see what sort of flowers the plant really has. They are beautiful, white, star-like flowers, an inch or so across, with six equal rays; and when we examine them, we see that we were right in our guess, and that they are indeed lilies. We find the upper half of the main stalk, and almost the whole length of all the branches, crowded with buds, but that never more than three or four on the main stalk, or any one branch, open on the same day. We also find that the plant is a night-bloomer, the flowers never opening until late in the afternoon, and fading early the next day. Seen at midday the plant has a deserted, desolate appearance; but in the evening, when adorned with perhaps a hundred of the dainty white stars, which seem almost suspended in the air—so slender are the branches—it reminds us of something ethereal. The three or four flowers which are in bloom at the same time on each branch are always grouped, as if they loved companionship of their sister stars.

This strange lily is the Amole, or Soap-Plant as it is more usually called. Its botanical name is *Chlorogalum pomeridianum*, which seems rather ponderous for so dainty a flower. The specific name means "in the afternoon," referring to the time of opening. The name of "Soap-Plant" comes from the fact that the bulb forms lather in water and has excellent cleansing properties. It has been used as a substitute for soap by the Indians, and to some extent by the Spanish-Californians. It is said that the Indians also make use of it to catch trout in small mountain streams, the plan

(*Continued on page 96*)

An Artificial Fertilizer*

Studies on the Influence of Fluorides on Plants

By A. Gautier and P. Clausmann

The well-known French scientists Armand Gautier and P. Clausmann, who have devoted several years of research to the part played by fluorine in living organisms, have just published in the *Comptes Rendus* of the French Academy of Sciences an account of their recent studies regarding the effect exerted by fluorides upon vegetation. Their previous investigations having established the fact that fluorine exists in all the tissues of both plants and animals, sometimes in very small proportions, but sometimes in abundance, as in the bones, the skin and the enamel of the teeth, they were led to the conclusion that this element is indispensable in the vital economy. They also proved that fluorine always accompanies phosphorus in the living cell, that it varies with this element, whose fixation it seems to occasion, and, finally, that it is eliminated in combination with the phosphorus. Since it is evident that the animal organism derives fluorine from the plant substances employed as food and that the latter obtain it from the fluorides and fluophosphates of the soil in which they grow, it occurred to these investigators to study the conditions favoring the assimilation of this element by plants and the effect upon the latter of a lack of fluorides on the one hand or of a liberal supply on the other.

They, therefore, began a series of experiments along this line in 1913, first making use of large flower pots, having a content of four liters each, all placed outdoors under the same conditions. In 1915 further experiments were made in short rows cultivated under the usual conditions of a market garden. Being dissatisfied with the results of these tests the experiments were repeated in 1916 and 1917 on a larger scale, the plants observed being studied in field culture. The results are stated as follows:

In our experiments in pots we attempted to compare cultures in soil as free as possible from fluorine with those made in the same sort of soil, but artificially supplied with fluorine. To secure a soil containing but little fluorine or containing this in an almost insoluble state, we first selected a very pure glass especially manufactured for these tests and reduced to fragments the size of a pea. Since this medium was found to be still too highly fluorated we made use the following year (1914) of a charcoal made from birch wood, pulverized and washed with hot acids and then with boiling water. This substance was the medium most nearly exempt from fluorine which we were able to prepare, containing only 1.87 mg. per kilo.

a. Cultures Upon Crushed Glass to Which Fluorides Have or Have Not Been Added.—These plant species were cultivated in the comparative manner in three pots of a capacity of four liters each, each being placed upon a saucer. In two of them the glass was placed (3,500 gr. each) mixed with a fertilizer of the following composition: Phosphate and carbonate of lime, nitrate of potash, sulphate of ammonia, carbonate of magnesia, silica and aluminum in colloid form, traces of zinc and of iron, and finally, a little bit of very fertile arable earth whose function was to provide microbian flora. This mixture possessed a permeability to water about equal to that of ordinary arable earth, but contained no fluorine except that of the glass, which was nearly insoluble as the glass had been washed free of its own dust. The desired fluorine was then added to these two pots in the form of a dilute solution of an alkaline fluoride. The third pot was filled with ordinary arable earth for the sake of controlling the experiment.

The first experiments were made with fourteen species of plants, belonging to the most various families, and included rye, barley, oats, buckwheat, peas, vetches, beans, morslave, mustard, flax, dandelions, tobacco, fennel, zinnia, etc. Most of these develop poorly in this vitreous milieu; this was specially the case with the peas, vetches, purslane, flax, dandelion, tobacco, fennel and zinnia. Fairly good results were given only by the oats, beans, mustard and California poppy (*escholtzia*). We concluded, therefore, that the vitreous soil formed chiefly of a sodic salt is not suited in general to vegetation. Furthermore, the glass used, although purified, still contained 123 mg. of fluorine per kilo, and by reason of this some uncertainty as to the correctness of our conclusions was felt. We, therefore, decided in 1914 to replace the glass by purified birch charcoal separated from its finest powder. As a source of fluorine we employed only the fluoride of potassium, 2.45 gr. per kilo of carbon or 0.835 grams per pot, taking care always to pour the drain waters into their respective pots, which were afterwards watered only with rain water. The charcoal soil was made up as follows: Washed charcoal 1,000 gr. (corresponding fluorine 0.00187 gr.; Al_2O_3 added in the state of colloid aluminum = 120 gr. (fluorine = 0); chalk = 730 gr. (fluorine = 0.002 gr.); humus, 27.3 gr.; very fertile arable earth = 66 gr. (fluorine = 0.007 gr.); $CaHPO_4$ = 24 gr.; KNO_3 = 34 gr.; Al_2SO_4 = 30 Gr.; NaCl 3 gr.; $MgCO_3$ 68 gr.; $MnCl_2$ .8 gr.; $ZnCO_3$ .07 gr.; SiO_2 employed in jelly or colloid forms 17 gr.; $FeSO_4$ 180 gr.; sodium arsenate 1.4 gr. It will be seen that this complete mixture, which was normally permeable to water and was composed of the indispensable biological and mineral fertilizing elements, contained only 11 mg. of fluorine per kilo., or 3.97 mg. per pot. The fluorated pots received 300 mg. of fluorine each, i. e. 77 times as much as the control pot; thus our three pots contain (a) a charcoal soil to which no fluorine has been added, (b) an artificially fluorated charcoal soil, (c) ordinary garden earth.

* * *

Of twelve species cultivated under similar conditions but with the addition or non-addition of fluorides, the influence of the fluorine was favorable to seven (cress, cabbage, California poppy, spinach, viper's bugloss, spurrey, and hemp); exerted no effect upon three (convolvulus, onion and rye); while it produced inferior crops in three (sweet peas, chick peas and centaury).

While this first examination was reasonably satisfactory, since out of twelve experiments seven were successful, we did not consider it absolutely conclusive even in the favorable cases, because of the very small crops obtained from only ten or twelve seeds and in the conditions involved by cultivation in pots; furthermore, since the source of fluorine was potassium fluoride we feared that the fecundity of the crops might have been influenced by the potassium in spite of the very small proportion of this metal present. For this reason we decided to examine the influence of the other fluorides upon vegetation, at any rate the most useful plants, when cultivated in the open field under ordinary conditions. Experiments on these lines were conducted in 1916 and 1917 and we shall shortly make known their results.

*Translated from *Comptes Rendus* (Paris).

The Law of Irreversible Evolution

(*Continued from page 87*)

organs and parts. The reversibility of the ascending evolution of a complex organ when this depends upon a reduced part is not impossible, therefore; it may be supposed, for example, that the secondary ventrals of the Teleostians will return in the course of time to the primary state by means of the complete disappearance of the corresponding ligaments.

When we are concerned with a part which is not reduced but which has undergone a change of form during the ascending evolution of an organ, then, strictly speaking, the indestructibility of the past also fails to exist, since the non-reduced part may change its form again through a new progressive evolution, although the primary state of the said part, and consequentially the primary state of the organ in question, may not be re-established. Hence it is not the indestructibility of the past which is the reason for the irreversibility of the evolution in this case. Let us take the example of the pelvis of the Triceratops. The postpubis of this pelvis exists in a very rudimentary state and since rudimentary parts tend to disappear, if the Triceratops had lived long enough his postpubis would certainly have disappeared. It is not the form of the curved ischium of the Triceratops, very different in form from the ischium of its remote Tetrapod ancestors, which could have prevented the return of its pelvis to the primary state.

Finally, if there be an ascending evolution of non-reduced parts (as in the case of the pelvis of the Stegosaurus) then it is the change of function which saves these parts from a retrogressive evolution; here again, therefore, the indestructibility of the past fails to exist. And it is evident that the same sort of reasoning applies equally well to the third law of the evolution of a complex organ.

To sum the matter up, the irreversibility of the evolution of a complex organ depends entirely upon the irreversibility of the evolution of the various parts, whether reduced or non-reduced, of which it is composed; and the second and third laws are no exception in this respect, for as we have seen, it is always the germinal basis of the first law upon which it ultimately rests.

As I remarked at the beginning of the present article, the majority of naturalists are familiar only with the first law of Dollo, which is only a part of his general law, although it is, to be sure, the most important and the most certain part.[31] In spite of possible exceptions, this general law is of extraordinary importance both for th edoctrines of biology and for evolutionary doctrines in general, and Dollo will always be considered, like Cuvier before him, as the discoverer of a great law of the organic world.[32]

A New Alloy

Because of the high temperature required for suitably hardening tools of tungsten high-speed steel Sheffield toolmakers have sought a substitute metal.

A new alloy produced by adding cobalt to chromium-carbon steel is reported to be best hardened by a temperature of 1,200° C. For most purposes the hardening required is obtained when the tool is cooled naturally in draft-free air. In a comparative test saws of "cobalt-crom," as the new steel is called, continued cutting for four days, it is stated without regrinding, while saws of tungsten high-speed steel were dulled in two days and those of carbon steel in half a day.—*American Machinist.*

[31]Besides the law of irreversible evolution Dollo formulated two others (reference of note 1. p. 165), that of discontinuous evolution (before de Vries) and that of limited evolution. In his later writings Dollo barely referred to these other laws. With respect to the former, see reference of note 13, p. 120; reference of note 6, p. 9; reference of note 9, pp. 139, 140. With respect to the latter, see reference of note 6, p. 9; reference of note 24. pp. 813. 820; second reference of note 9, p. 131.

[32]To the list of the works of Dollo upon evolution may be added the important volume by O. Abel, Principles of the Paleobiology of the Vertebrates, 1912 (in German), which contains nearly all of Dollo's examples and many others besides. Dolo's law is discussed therein on pp. 616-18.

Constitution of the Sun's Nucleus and Atmosphere

A previous paper by A. Véronnet dealt with masses of homogeneous gas. This extends the investigation to mixtures, ignoring the small difference between coefficients of dilatation and compressibility. Under a pressure of 1,500 atmos. the gases reach a density one-third of their limiting density, giving a sudden point of inflection in the density curve and suggesting a surface of separation between the main body of the sun and its lighter envelope. With his previous value of 1.41 for density and 6,000° C. for temperature he finds a mean atomic weight for the nucleus (supposed diatomic) of about 110, nearly that of silver. Then assuming a mixture of 40% Ag, 30% Ta, and 10% each of Fe, Ca, and Na, in order to reproduce exactly his theoretical atomic weight he investigates the change of density with depth, finding the density doubled at about 2 km. and nearly 99% of its central value at 100 km., corresponding to a depth of 1 km. on the earth; at greater depths than this the density is therefore practically uniform. In the atmosphere it is very different. The density is halved at a height of 2 km. and reduced to only 1% at 30 km. The heaviest vapors (Pt, Au, Hg, etc.) cease to have any effect at 20 km., and the silver group (Ag, Cd, Sn, etc.) towards 30 km.

Thus in passing from a height of 20 km. to a depth of 10 km. in reference to the suggested surface, the density increases 110-fold, or from a gaseous to a liquid value, confirming the definiteness of the separating surface, and making it analogous with that of the earth. Now, our clouds hang lower in winter, when convection is less active. So the author suggests that on the sun, if its temperature were lowered, a similar effect would take place, and if the vapors fell so low as 20 km. the heavy gases would appear, and the sun's light having to traverse a layer eight times as dense would look red and much less bright. So also when its temperature was higher it might have been a white star.—*Science Abstracts.*

West Virginia Well Down 7,579 Feet

EVIDENCE sustaining the temperature hypothesis of a cooling globe has been obtained by the U. S. Geological Survey in the large number of thermometer readings made during the sinking of a well near Valley Falls, W. Va., to a depth of 7,579 ft. The temperature near the surface was 52°, whereas at a depth of 7,500 ft. it was approximately 170°. A slight reduction in the steepness of the gradient is noticed below 6,500 ft.

The well was designed for a test of the Clinton sand on the prominent geological arch which is deeply cut by a river at the point where the well was put down. It was remarkable for the fact that it was dry and no casing was used below 2,000 ft. Caving started near the bottom of the well, however, and the drillers were forced to give up their attempt to reach a depth of 8,000 ft. The log of the well is being studied by the State Geologist of West Virginia.

The well was bored by the same company which put down a Goff well near Clarksburg, in northern West Virginia. That well, at the time of its drilling, about nine months ago, was the deepest well in the world. The record prior to that time had been held by a boring at Czuchow, in Silesia, which was 7,340 ft. deep.—*Eng. and Mining Jour.* (New York).

The Lilies of the Field

(*Continued from page* 94)

being to place in the shallow water of rapids a quantity of the lather, which will then mix thoroughly with the water by the time it reaches the deep pools where the trout lie. The fish are stupefied by the plant drug and rise to the surface, where they are easily caught.

The Zygadene (*Zygadenus fremontii*) is a widely-distributed California plant that resembles the soap-plant very much in its appearance and manner of growth. However, its radical leaves are deeply channeled and are not so crinkly as those of the soap-plant; they are also somewhat heavier. The stalk is much heavier, and usually not more than one-and-a-half or two feet in height. There are few branches, and the flowers are in a true spike. In the southern coast ranges, the Zygadine grows widely over the foothills, mesas and mountain slopes. It prefers some moisture, but flourishes fairly well in soil that dries out rapidly after the winter rains cease. It is a trail-loving plant, and often we find the trail bordered with it, almost as if it were planted there; and frequently, where the trail is not too much used, we find it trying to usurp a place in the very middle of the path. The spikes of nearly pure white flowers are attractive, and are quite generously gathered by flower-lovers. Its habit of seeding profusely will always cause it to be plentiful.

There are several of the Zygadenes, one being found quite generally throughout the eastern part of the United States. Another is the Death Camass of northern California, Oregon and Washington, the bulb of which is very poisonous to animals, except hogs, which fact has given it the name of "Hog's Potato" in the region where it grows. All the Zygadenes are more or less poisonous, which has caused our Government to issue a pamphlet concerning them.

Among the wild flowers which make a brave display by producing a multitude of small blooms there are some lilies. Thus the Brodiæas may paint a hillside purple in April, and almost as vividly as the Lupines do in May. Then in June you may find gentle slopes that are yellow from the countless blooms of Golden-Stars (*Bloomeria aurea*), a light orange-colored lily with a slender stalk some eight or ten inches tall that is crowned with an irregular, spreading umbel of perhaps forty or fifty twinkling golden stars and beautiful elongated-oval buds. The individual blooms will repay a close inspection. You will find the petals are striped with two dark lines, and that the anthers are bright green.

There are two other Bloomerias in southern California. One is *B. clevelandi*, which is found in the region of San Diego. It does not seem to be blest with a common name. This has green-nerved petals, and is not nearly so attractive as its more northern sister. The other, which I have never seen mentioned in any botanical or other literature, is almost a pure white.

Perhaps the most striking of all the lilies are the Yuccas. There are several of these in the Southwest, two of which attain their highest perfection in southern California. These are commonly known as the "Spanish-Bayonet" and the "Joshua-Tree."

The Spanish-Bayonet (*Yucca whipplei*) is widely distributed in southern California and Arizona, and has a wide range in altitude. From the foothills which run down close to the sea, it flourishes to altitudes of five or six thousand feet. Almost anywhere you may go in the South, it thrusts itself upon your sight. If it bore no flowers it would still be a striking feature of the landscape on account of its hemispherical clumps of long, dagger-armed, bluish-green leaves. There is no trunk, and the leaves are thrust upward and outward at every possible angle from the center, from which in due season rises a ten- or fifteen-foot shaft, its upper half an immense standard of creamy-white flowers.

Just what this "due season" of blooming on the part of the Spanish-Bayonet is no one seems to know. Some say that the plant should bloom the second year from the seed, while others claim it is the third year. Then there are those who assert that "it blooms whenever it gets ready." A friend of mine near Santa Barbara is among these, and seems to have the evidence to support his convictions. He carefully transplanted a large number of young yuccas which were just well started from the seed. None of them bloomed the second year. Some bloomed the third year, some the fourth, some the fifth, and some not at all. After the Spanish-Bayonet blooms, it dies.

The magnificence of the Spanish-Bayonet's floral spire is only fully appreciated by those who have seen it. Some of the spikes contain as many as five thousand of the waxen bells, which are an inch or more in diameter! The time of blooming is from April to June, according to the altitude. The flowers at the base open first and have already begun to fade when those at the top are coming into bloom. Thus the time when the Spanish-Bayonet is at its perfection is short; but for a period of about a month there are enough of the flowers in bloom to make the stalk a conspicuous object on the hillside. Even after the flowers are gone and the date-shaped seed-pods take their place, the Yucca still attracts the eye from afar.

The dagger-pointed leaves of the Yucca command the highest respect from all who traverse the country in which it abounds. Cloth of the closest texture is no protection whatever against them, and even the toughest, hardest leather is no sure armor. They pierce ordinary shoes as if they were made of paper. Their needle-like tips are poisonous to some extent, too, and wounds caused by them are apt to be sore for several days.

The Spanish-Bayonet has several counts to its credit. Not the least of these, in my estimation, is that it chooses for its home rocky hillsides and other barren places, and there does a most commendable part in beautifying the landscape. Then it furnishes food for the Indians, who use both the seed and the tender young flower shoots. The latter they esteem a great delicacy when roasted with hot stones, after the native fashion. From the leaves the Indians get a soft fiber which they weave into a cloth that is used for lining coarser materials.

The Joshua-Tree (*Cleistoyucca arborescens*) is a desert plant, attaining its largest stature and most luxurious growth in the Mohave Desert. There it commonly grows to a height of fifteen or twenty feet and about as many inches in diameter. Extra large individuals may reach two feet in thickness and thirty feet in height. They are strange and weird in appearance. It is doubtful if the world produces more grotesque objects in the way of trees. Until the trunks reach the height of eight or ten feet they are set with bristling leaves from the ground up. Then the tree begins to bloom, and the branching commences by forking at the top. Each fork then divides, and the branching thus goes on, until the top is a mass of short stubby stems sticking out at all sorts of angles. The leaves along the trunk gradually droop and hang downward. In old age the lower part of the trunk becomes entirely bare. The branches are apt to remain covered, however, and the end of each is armed with tufts of long dagger-like leaves that successfully keep all would-be intruders at a respectful distance.

In March and April the large clusters of greenish white flowers appear, thrust out as it were from the tufts of leaves at the ends of the trunk and stubby branches. Each cluster contains numerous bells which are from one to two inches across. At that time the yucca-covered desert wears an attractive dress. As you ride swiftly by on a railway train, you may become wildly enthusiastic over the beauty of the Yucca. But it is well that you view the flowers from some little distance, for they give off a strong fetid odor that is exceedingly disagreeable. It would seem as if the bunch of dagger-leaves with which each flower cluster is surrounded were enough protection, without the addition of the horrible smell. Whenever I see the Joshua-Trees I think how considerate they have been in choosing to make their home where few men have a desire to live.

Just how and when this desert yucca came by its name of "Joshua-Tree" no one seems definitely to know. The name dates from the earliest emigrant trains that crossed the deserts, and it is claimed by some that these early argonauts saw in the grotesque yuccas signs which pointed to a land of promise.

Nomographic Charts for the Aerial Propeller

THERE has recently come into use a means for the graphical solution of exponential formulæ, which is similar in principle to the "Polar Logarithmic Diagrams" devised by M. Eiffel, in that it depends on the reduction of an exponential to a linear form by the use of logarithms, and the employment of logarithmic scales. This device consists in the construction of diagrams called nomographic charts, or alignment charts, from which the required results may be obtained by simply connecting the points representing the given data by straight lines and then reading off the intercepts on the proper scale, the method being similar to that of using a slide rule.

Prof. Slocum describes with examples the method of applying nomographic charts to propeller calculations, assuming that the performance of a given type of propeller is given by an exponential formula based on actual results of tests. He states that the usual assumptions that the thrust varies as N^2D^4 and the horsepower N^3D^5 may often give erroneous results, as was found by analysis of experimental results obtained by M. Eiffel and Capt. Dorand.—*Aerial Age Weekly.*

SCIENTIFIC AMERICAN SUPPLEMENT

Founded 1876

Published by Scientific American Publishing Co.

New York, Saturday, August 9, 1919

Munn & Co., 233 Broadway, New York

Charles Allen Munn, President; Orson D. Munn, Treasurer
Allan C. Hoffman, Secretary, all at 233 Broadway

The Scientific American Publications

Scientific American Supplement (established 1876) per year $5.00
Scientific American (established 1845) 5.00
The combined subscription rates and rates to foreign countries including Canada, will be furnished upon application.
Remit by postal or express money order, bank draft or check.

Scientific American Publishing Co.
233 Broadway, New York

The purpose of the Supplement is to publish the more important announcements of distinguished technologists, to digest significant articles that appear in European publications, and altogether to reflect the most advanced thought in science and industry throughout the world.

Back Numbers of the Scientific American Supplement

SUPPLEMENTS bearing a date earlier than January 1st, 1918, can be supplied by the H. W. Wilson Company, 958-964 University Ave., Bronx, New York, N. Y. Please order such back numbers from the Wilson Company. Supplements for January 1st, 1918, and subsequent issues can be supplied at 10 cents each by SCIENTIFIC AMERICAN PUBLISHING Co., 233 Broadway, New York.

Table of Contents

yuccas

ller

for the
is sim-
grams"
reduc-
use of
scales,
grams
, from
simply
ata by
on the
' using

method
alcula-
ype of
sed on
al as-
horse-
s was
ned by

AN

Co.

easurer

$5.00
5.00
untries
n.
heck.

h the
ished
ppear
reflect
ustry

n

nuary
Com-
N. Y.
Com-
ubse-
h by
lway,

e in a
ranch
posed
thor-
t ap-
f the
nical,

who
k ap-
nited

,
Y.